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Analyses of Selected Physical and Chemical Characteristics of Dauphin Lake, Manitoba

J.A. Babaluk and M.K. Friesen

Central and Arctic Region
Department of Fisheries and Oceans
Winnipeg, Manitoba R3T 2N6

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by

J.A. Babaluk and M.K. Friesen

Central and Arctic Region

Department of Fisheries and Oceans

Winnipeg, Manitoba R3T 2N6

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TABLE OF CONTENTS

	Page
ABSTRACT/RÉSUMÉ	iv
INTRODUCTION	1
MATERIALS AND METHODS	1
Description of the study area	1
Bathymetry and morphometry	1
Water sampling	1
Sediment sampling	2
RESULTS AND DISCUSSION	2
Bathymetry and morphometry	2
Analyses of water samples	3
Temperature and heat budget	3
Secchi depths	3
Chlorophyll	3
Dissolved oxygen	3
pH	3
Conductivity and major ions	3
Total suspended solids and suspended nutrients	4
Other characteristics	4
Correlations	4
Sediment Analyses	4
Particle size	4
Organic matter and nutrient elements	5
SUMMARY	5
ACKNOWLEDGMENTS	5
REFERENCES	5

LIST OF TABLES

Table		Page
1	Dates of ice-off and freeze-up for Dauphin Lake, 1979-1988.	8
2	Dates and stations for collections of physical and chemical data for water from Dauphin Lake, 1982	8
3	Some estimates of method precision for synthetic standards and Canadian Shield water	9
4	Some morphometric calculations for Dauphin Lake	10
5	Summary of morphometric data for Dauphin Lake, Lake Manitoba and Lake Winnipeg basin.	11
6	Surface inflow and outflow of major rivers and streams for Dauphin Lake, 1982	12
7	Physical and chemical data, Dauphin Lake, February 23-24, 1982	13
8	Chemical analyses of water samples from Dauphin Lake, February 23-24, 1982	14
9	Physical and chemical data, Dauphin Lake, 1982	15
10	Chemical analyses of water samples from Dauphin Lake, 1982	24
11	A comparison of some physical and chemical data ranges of waters from three Manitoba lakes	27
12	Correlation coefficients for selected physical and chemical characteristics of Dauphin Lake water at each sampling period, 1982	28
13	Correlation coefficients for selected physical and chemical characteristics of Dauphin lake water for	
14	Percent dry weight of total carbon, carbonate, organic carbon where $C_o = IC-C_i$, total nitrogen and total phosphorus determinated by chemical analyses from surface sediment samples less than 2 mm in dia. from Dauphin Lake, Sept., 1983 and May, 1984	30
15	Particle size distribution by weight of surface sediment samples from Dauphin Lake, Sept., 1983 and May, 1984	32
16	Percent particle size distribution of offshore surface sediments of Dauphin Lake, Lake Manitoba and Lake Winnipeg	33

LIST OF FIGURES

Figure		Page
1	Bathymetric map of Dauphin Lake showing water sampling stations, 1982 and sediment sampling stations, 1983 and 1984	34
2	Mean values of physical and chemical characteristics for all stations versus time, Dauphin Lake, 1982	35
3	Distribution of Secchi depths, Dauphin Lake, 1982	37
4	Distribution of chlorophyll at 0.5m depth, Dauphin Lake, 1982	38
5	Distribution of specific conductance, Dauphin Lake, 1982	39
6	Distribution of sodium at 0.5 m depth Dauphin Lake, 1982	40
7	Distribution of sulphate at 0.5 m depth, Dauphin Lake, 1982	41
8	Distribution of chloride at 0.5 m depth, Dauphin Lake, 1982	42
9	Distribution of total suspended solids at 0.5 m depth, Dauphin Lake, 1982	43
10	Distribution of suspended phosphorus at 0.5 m depth, Dauphin Lake, 1982	44
11	Distribution of suspended nitrogen at 0.5 m depth, Dauphin Lake, 1982	45
12	Distribution of suspended carbon at 0.5 m depth, Dauphin Lake, 1982	46
13	Distribution of sand, silt and clay sediments, Dauphin Lake, 1983 and 1984	47
14	Trilinear plot of sand, silt and clay of surface sediments, Dauphin Lake, 1983 and 1984	48

ABSTRACT

Babaluk, J.A., and M.K. Friesen. 1990. Analyses of selected physical and chemical characteristics of Dauphin Lake, Manitoba. Can. Manuscr. Rep. Fish. Aquat. Sci. 2081: iv + 48 p.

Dauphin Lake, a prairie lake, 522 km^2 with a mean depth of 2.1 m was surveyed in 1982 for selected physical and chemical characteristics. Sediment samples were collected in 1983 and 1984. Horizontal gradients for some of the characteristics measured occurred briefly at peak river discharge in spring. Thermal stratification occurred only under ice. Secchi depths ranged from 0.10 - 1.10 m. Dissolved oxygen concentrations were near or above saturation. Chlorophyll values ranged from 0.1 - 35.3 $\mu g \cdot L^{-1}$. Conductivity ranged from 310 - 770 $\mu S \cdot cm^{-1}$. Relative abundances of major ions were $Ca^{++}>Mg^{++}>Na^{+}>K^{+}$ and $HCO_3^{-}>SO_4^{=}>Cl^{-}$. Nitrogen was depleted during the open water season while phosphorus concentrations tended to increase during the same period. Offshore sediments were clayey silt or silty clay while near shore sediments were low in clay. Offshore sediments generally had higher levels of organic carbon, carbonate, nitrogen and phosphorus. Data were compared with Lake Winnipeg and the south basin of Lake Manitoba.

Key words: bathymetry; heat budget; limnology; morphometry; ions; nutrients (mineral); sediment analysis; water analysis.

RÉSUMÉ

Babaluk, J.A., and M.K. Friesen. 1990. Analyses of selected physical and chemical characteristics of Dauphin Lake, Manitoba. Can. Manuscr. Rep. Fish. Aquat. Sci. 2081: iv + 48 p.

Le lac Dauphin qui est un lac des prairies de 522 km^2 et de 2,1 m de profondeur moyenne, a été l'objet en 1982 d'une étude sur certaines caractéristiques physiques et chimiques. Des échantillons de sédiments ont été prélevés en 1983 et 1984. Certaines caractéristiques mesurées ont présenté brièvement des gradients horizontaux au printemps lorsque les débits des cours d'eau sont les plus forts. Il n'y avait stratification thermique que sous la glace. Les profondeurs de Secchi variaient entre 0,10 et 1,10 m. Les concentrations d'oxygène dissous approchaient ou dépassaient le niveau de saturation. Celles de la chlorophylle variaient entre 0,1 et 35,3 $\mu g \cdot L^{-1}$. La conductivité allait de 310 à 770 $\mu S \cdot cm^{-1}$. Les abondances relatives des principaux ions allaient selon l'ordre suivant: $Ca^{++}>Mg^{++}>Na^{+}>K^{+}$ et $HCO_3^{-}>SO_4^{=}>Cl^{-}$. L'azote s'est épuisé pendant la période des eaux libres, tandis que les concentrations de phosphore avaient tendance à augmenter pendant la même période. Les sédiments du large étaient de l'argile limoneuse ou du limon argileux, tandis que les sédiments littoraux contenaient peu d'argile. Les sédiments du large avaient en général des teneurs plus élevées en carbone organique, en carbonate, en azote et en phosphore. Les données ont été comparées à celles du lac Winnipeg et du bassin méridonional du lac Manitoba.

Mots-clés: bathymétrie; bilan thermique; limnologie; morphométrie; ions; éléments nutritifs (minéraux); analyse des sédiments; analyse de l'eau.

INTRODUCTION

In 1982, a cooperative fisheries rehabilitation research program was initiated on Dauphin Lake, Manitoba (51°17'N, 99°48'W) (Fig. 1) by the Canada Department of Fisheries and Oceans and the Manitoba Department of Natural Resources. The objective of the program was to develop and test new biological and hydrological techniques for the rehabilitation of fisheries in the fresh waters of Canada. Emphasis was on the rehabilitation of the walleye, Stizostedion vitreum vitreum (Mitchill), one of the most economically important freshwater fish species in Canada (Scott and Crossman 1973).

Historically, Dauphin Lake had one of the most productive commercial fisheries in Manitoba; more than 50% of the catch was made up of walleye (Cunningham 1935; Butler 1950; and H. Valiant, Manit. Dep. Nat. Resour. Dauphin, personal communication). This percentage has declined dramatically in the last four decades. During the 1950's the average annual walleye catch was approximately 50 000 kg, while during the 1970's the harvest had declined to an average annual catch of 2 500 kg (Babaluk et al. 1984). Catches of walleye in the 1980's have increased but are still less than catches recorded during the 1950's and are composed mainly of single year classes (authors' unpublished data). Dauphin Lake was selected for the fisheries rehabilitation program because it exemplified a lake that had shown a dramatic decline in the commercial and recreational walleye fisheries; it is of a size (approx. 522 km^2) that can be reasonably sampled and any new rehabilitation techniques developed should be applicable to both larger and smaller commercially and recreationally fished lakes with similar problems.

Collection of baseline data for the fisheries rehabilitation research program included surveys of some physical and chemical characteristics of Dauphin Lake. This report presents and discusses the findings of the 1982 water sampling survey and compares some Dauphin Lake data with data from the south basin of Lake Manitoba (51°00'N, 98°45'W) and Lake Winnipeg (52° 00'N, 97°00'W) as these lakes have a similar geological origin and are also part of the Nelson River system. Data and analyses of Dauphin Lake sediments collected during 1983 and 1984 are also presented and discussed. Data from surveys of physical and chemical characteristics of the lake conducted in 1983, 1984 and 1985 are presented in Babaluk and Friesen (1990).

MATERIALS AND METHODS

DESCRIPTION OF THE STUDY AREA

Dauphin Lake is a remnant of glacial Lake Agassiz and is located in west central Manitoba (Fig. 1, inset). The lake is oriented in a north-northwest direction with a maximum length of 42 km and maximum width of 20 km. It has a surface area of approximately 522 km^2, mean depth of 2.1 m, maximum depth of 3.5 m and volume of approximately 1.1 km^3. Freeze-up normally occurs in November and ice-off occurs in late April to mid-May (Table 1). The drainage basin of the lake is approximately 8 700 km^2 and is bounded by the Duck Mountains to the west, Riding Mountain to the south and southwest and the divide between Dauphin Lake and Lake Manitoba to the east. The drainage system includes rivers and streams with headwaters in the Duck and Riding mountains that empty into the lake from the south and west. They pass through agricultural and urban areas of ground moraine and glacial Lake Agassiz deposits that overlay a sequence of Post-Cambrian sedimentary rocks (see Davies et al. 1962). The Mossy River, the only outlet, flows in a northerly direction into Lake Winnipegosis then through Lake Manitoba, Lake Winnipeg, Nelson River and eventually into Hudson Bay. Other details of the drainage basin are described by the Manitoba Water Commission (1984). The shoreline of Dauphin Lake is composed mainly of sand, gravel, rock and boulder beaches and marshes. Stewart-Hay (1951) and the Manitoba Water Commission (1984) describe other details of the shoreline. There is only one island, comprised of boulders, located approximately 2 km off the mouth of the Turtle River. A few rock spits are also present around the lake.

BATHYMETRY AND MORPHOMETRY

The bathymetric map of Dauphin Lake (Fig. 1) was prepared from a map originally produced by Manitoba government personnel based on a water level of 260.2 m above sea level (a.s.l.) (Manit. Dep. Mines Nat. Resour. Water Resour. Br., file no. 85-4-1014). This is the mid-point of the range of 260.0 - 260.4 m a.s.l. that the Dauphin Lake Advisory Board recommended lake levels be kept within (Manitoba Water Commission 1973, 1984). Theoretically, the water level of the lake can be maintained between these levels by a dam located on the Mossy River. However, lake levels have not been strictly maintained within this range (Manitoba Water Commission 1984) and as a result, bathymetric and morphometric characteristics vary from year to year.

Surface area and shoreline length for the lake were measured directly from a 1:125 000 scale topographic map (Canada Department of Energy, Mines and Resources, Surveys and Mapping Branch, Map 62 O/SW, edition 1) using a Hewlett-Packard 9830A computer with a Hewlett-Packard 9864A digitizer (precision level ±1.5%). Franzin and McFarlane (1976), using the same method, estimated cartographic error (changes in scale and drafting error) to be approximately 5%. They also estimated that depth measurements were subject to an error of approximately ±5%. The three error terms yield a total error of approximately ±10% on volume calculations. The morphometric characteristics for Dauphin Lake were calculated following the procedures outlined by Hutchinson (1957).

WATER SAMPLING

Water samples were collected and physical characteristics were measured periodically during the open water period of 1982 and once during the winter (February, 1982). Nine stations

sampled during February, 1982 are shown in Fig. 1 (stations A-I). The stations selected for open water sampling (Fig. 1; stations 1-21) were located along four transects: three oriented in an approximate northeasterly line and one in a northwesterly line. Stations were located by magnetic compass bearings and vessel or vehicle speed. Dates and stations sampled are listed in Table 2.

Water temperature profiles were determined using a Yellow Springs Instruments tele-thermometer (model #43 TD) (precision: ±0.5°C). Heat budgets were calculated following Wetzel (1975). Dissolved oxygen concentrations were determined using the Winkler method (precision: level 10.0 mg $O_2 \cdot L^{-1}$; S.D. ±0.2 mg $O_2 \cdot L^{-1}$) (Stainton et al. 1977) and saturation levels of dissolved oxygen were calculated from Elmore and Hayes (1960). A Secchi disk was used to determine water transparency. Water samples for chlorophyll, pH and conductivity were taken with a 1.5 L Kemmerer sampler at the surface, at 1 m and at a depth approximately half the distance between the 1 m depth and the lake bottom. A 200 mL subsample was processed for chlorophyll using a methanol extraction method and Turner fluorometer (model #111) (precision: level 1.2 µg chlorophyll $\cdot L^{-1}$; S.D. ±0.12 µg chlorophyll $\cdot L^{-1}$) (M. Stainton, Can. Dep. Fish. and Oceans, Winnipeg, personal communication). Conductivity was measured using a Radiometer conductivity meter (model #CDM 26) (precision: level 150 $\mu S \cdot cm^{-1}$; S.D. ±0.01 $\mu S \cdot cm^{-1}$) and pH was measured using a Radiometer pH meter (model #29) (precision: level 8.49; S.D. ±0.02).

Water samples for dissolved element and nutrient analyses were collected from a depth of 0.5 m and analysed at the Freshwater Institute Analytical Laboratory following the procedures of Stainton et al. (1977). Estimates of precision for these procedures are given in Table 3. The concentration of HCO_3^- was estimated by measuring total dissolved inorganic carbon (D.I.C.) and multiplying the measured concentration by 0.972 which is the value given by Wetzel (1975) as being the proportion of D.I.C. that is present as HCO_3^- at pH 8. Results of analyses are given in $\mu g \cdot L^{-1}$ or $mg \cdot L^{-1}$ for comparison with other studies (eg. Can. Dep. Environ. 1978) and in some cases were also converted to millimoles $\cdot m^{-3}$ or moles $\cdot m^{-3}$ isopleths for comparison with Lake Winnipeg (Brunskill et al. 1979) and unpublished Lake Winnipeg data (G. Brunskill, Can. Dep. Fish. and Oceans, Winnipeg, personal communication). Correlation coefficients (r; $P<0.05$) were computed for 1982 data for selected physical and chemical characteristics. Isopleths were drawn for characteristics which showed distinct areal patterns.

SEDIMENT SAMPLING

Sediment samples were collected at stations 6-20, inclusive, in September, 1983 and at stations 1,3,4,5,18 and 20 in May, 1984. An additional station (M) was sampled for sediments in September, 1983, only (Fig. 1). A Birge-Ekman type grab was used to sample all stations except where a gravel or cobble substrate was encountered where a pneumatic grab (Burton et al. 1985) was used. The latter sampler could be used only at stations with depths less than 1.5 m. At least two cores containing 10-70 g of sediment were removed from each grab sample at each station using a tube 3.0 cm in diameter and 25.0 cm long. Samples were washed through a 2 mm mesh sieve, dried at 110°C and both fractions were weighed. For particle size analyses, samples <2 mm in diameter were freeze-dried and a 10 g subsample of sediment was analysed using the Fast Analysis of Sediment Texture (F.A.S.T.) method (Rukavina and Duncan 1970). Organic carbon, carbonate and nitrogen content of sediments at most stations and phosphorus content for some stations were analysed chemically following Stainton et al. (1977). Organic carbon was estimated from the difference between total carbon and carbonate as well as by loss on ignition (L.O.I.). One sample was analysed from each station except stations 17 and 18 where two samples from each Birge-Ekman grab were analysed. A third sample at station 17, collected from the sediments adhering to the boat anchor was also analysed. These additional samples were analysed because of obvious visual and textural differences. L.O.I. was determined from sediment dried overnight at 420°C and for one hour at 850°C. Organic content (%) was estimated from the difference in weight of samples at 110°C and 450°C divided by 2.54 to adjust for inorganic substances lost (Teller and Last 1979).

RESULTS AND DISCUSSION

BATHYMETRY AND MORPHOMETRY

Figure 1 shows the bathymetry of Dauphin Lake based upon a level of 260.4 m a.s.l. and Table 4 presents some morphometric calculations based on this lake bathymetry. A summary of morphometric data from Dauphin Lake, Lake Manitoba (south basin) and Lake Winnipeg (south basin) is shown in Table 5. All are relatively shallow with a long fetch and have similar developments of shoreline and volume. Dauphin Lake differs in that the shoreline to area ratio is greater.

Water residence time in Dauphin Lake (τ = volume of entire lake ÷ annual outflow via Mossy River) estimated using hydrological data from Canada Department of Environment (1983b, 1984, 1985 and 1986) and our morphometric data was 8.2 years in 1982, 1.9 years in 1983, 6.2 years in 1984 and 3.3 years in 1985 with a mean of 4.9 years over the four year period. The estimated mean water residence time in Dauphin Lake was greater than the mean of 3.3 years (range of 2.9 - 4.3 years) calculated for the whole of Lake Winnipeg for 1969-1974 (Brunskill et al. 1980). This is due to the smaller relative influence of annual discharge of the major inflowing rivers of Dauphin Lake. Residence time for Dauphin Lake is much shorter than the 15.8 years we estimated for the south basin of Lake Manitoba from data in Teller and Last (1979) (Lake Manitoba calculations do not include the influence of groundwater influx and outflow). The shorter residence time for Dauphin Lake is due to the comparably larger influence of inflowing rivers. Monthly and total discharges during 1982 for the major inflowing rivers to Dauphin Lake are given

in Table 6. Total discharge from these rivers in 1982 varied from 2 910 cubic decapeters (dam^3) from Mink River to 45 400 dam^3 from Turtle River. Most of the discharge (79%) occurred during spring run-off in April and May (Can. Dep. Environ. 1983b). Although renewal times differ from year to year with variations in precipitation and influx of ground water, the large range of residence times noted for Dauphin Lake probably was due mostly to human manipulation of the lake level at the Mossy River dam.

ANALYSES OF WATER SAMPLES

Physical and chemical data for water samples collected from Dauphin Lake during February, 1982 are presented in Tables 7 and 8, respectively. Physical and chemical data for water samples collected during the open water season, 1982 are presented in Tables 9 and 10, respectively. Mean values of various physical and chemical characteristics for all stations sampled in 1982 plotted against time are shown in Fig. 2. Distribution of physical and chemical characteristics which showed areal gradients in 1982 are displayed as isopleths in Figs. 3-12, inclusive.

Temperature and heat budget

Dauphin Lake warms quickly after ice-off and water temperatures tend to follow air temperatures thereafter (Schaap 1987). As expected for a very shallow lake (mean depth = 2.1 m, maximum depth = 3.5 m), no thermal stratification was found during the 1982 open water season (Table 9) although it did occur under the ice (Table 7). Horizontal temperature gradients found in Lake Winnipeg (Brunskill et al. 1979) and attributed to the large inflowing rivers, were not detected in Dauphin Lake (Table 9). Inverse temperature stratification under the ice with no consistent stratification during the open water season also occurred in Lake Winnipeg (Brunskill et al. 1979).

Summer and winter heat budgets were calculated according to Wetzel (1975) using data collected July 21 and 22, 1982 from stations 3, 9 and 15 (Table 9) and February 23 and 24, 1982 from stations B, E and G (Table 7). The summer heat budget (3 500 $cal \cdot cm^{-2}$) plus winter heat budget (7 600 $cal \cdot cm^{-2}$) yielded an annual heat budget of 11 100 $cal \cdot cm^{-2}$. The relatively high winter heat budget was due to the high proportion of ice to water (Table 7). The total heat budget for the lake was approximately one-half that of the south basin of Lake Winnipeg and one-third that of the north basin (Brunskill et al. 1979). The relatively low value for Dauphin Lake is the result of its shallow basin.

Secchi depths

The low secchi depths for the 1982 open water period ($\bar{x}$ = 0.33 m, range = 0.10 - 1.10 m) (Table 9) were expected due to the shallowness of the lake, the long fetch and fine, resuspended bottom sediments. Secchi depths were relatively high in May just after ice-off (Fig. 2A, Table 9) but from late spring to late fall no seasonal changes were evident. Regional differences in the lake were found occasionally (Fig. 3). Large regional differences in Secchi depths were noted for the May, 1982 sampling period with the lowest values occurring in the area of the Wilson and Vermilion river mouths and the highest value at station 6 (Fig. 1 and 3). At other sampling times, gradients were weak or non-existent. Secchi depths for Lake Winnipeg (G. Brunskill, unpublished data), although occasionally higher, were generally in the same range as found in Dauphin Lake (Table 11).

Chlorophyll

Chlorophyll values for the 1982 open water period ranged from 2.2 - 35.3 $\mu g \cdot L^{-1}$ ($\bar{x}$ = 12.0 $\mu g \cdot L^{-1}$) but were generally in the 4.0 - 20.0 $\mu g \cdot L^{-1}$ range (Table 9). These values were similar to those previously measured in Dauphin Lake by Canada Department of Environment (1978) (Table 11). Values in February, 1982 ranged from 0.1-2.0 $\mu g \cdot L^{-1}$ ($\bar{x}$ = 0.5 $\mu g \cdot L^{-1}$) (Table 7). Discernible horizontal gradients for chlorophyll distribution occurred during all sampling periods (Fig. 4). Areas of relatively high values were usually found in the central region of the lake except in late August when higher chlorophyll values were observed in the southeast region of the lake. Chlorophyll values reached maximum levels in late July and were maintained until the end of October (Fig. 2B). Since regions of high chlorophyll values do not occur in the vicinity of river mouths, it is assumed that the chlorophyll in the lake is due to algae and not to terrestrial vegetation. Chlorophyll values tend to be 5.0 - 10.0 $\mu g \cdot L^{-1}$ higher that those from Lake Winnipeg (G. Brunskill, unpublished data) but comparisons must be made cautiously since different extraction methods were used.

Dissolved oxygen

Dissoved oxygen levels were consistently near or above saturation during the open water period and under winter ice cover (Tables 7 and 9) and showed no vertical or horizontal gradients. This indicates a high level of photosynthetic activity and/or a thorough mixing by wind of the lake during the open water period and a high level of photosynthetic activity and/or inflow of oxygenated ground water during the winter. Dissolved oxygen levels were similar to past records for Dauphin Lake and Lake Winnipeg (Table 11).

pH

Values of pH ranged from 7.89 - 8.64 but generally were slightly above 8 (Tables 7 and 9). These values were similar to previous measurements for Dauphin Lake as well as for Lake Manitoba and Lake Winnipeg (Table 11).

Conductivity and major ions

Conductivity was appreciably higher under the ice during the winter than during the open water season (Fig. 2C) due to the "freeze-out" of ions below the thick layer of ice (Table 7) (mean thickness = 0.87 m). Winter values were generally similar at all stations (range = 710 - 770 $\mu S \cdot cm^{-1}$) (Table 7) because of no effects

from wind due to ice cover and low discharge from the rivers and streams. Conductivity during the open water season of 1982 ranged from 310 - 600 $\mu S \cdot cm^{-1}$ (Table 9).

The greatest range of conductivity and ion values occurred during the May 26-28 sampling period. This was probably because of the dilution effect from melting ice and snow that resulted in areas of relatively low conductivity. Also, increased discharges from rivers and streams with higher conductivities resulted in higher values near the mouths of the rivers and streams (Fig. 5). Canada Department of the Environment (1983b) and Cobb and Flannagan (1987) reported similar results. The most distinct gradient existed near the mouth of the Valley River and less pronounced gradients were noted near river inflows in the south and southwest. Moderate northeast winds during the sampling period (Can. Dep. Environ. 1983a; J. Bendell, Can. Dep. Environ., Winnipeg, unpublished data) may have influenced the shape and direction of the combined rivers' plume in the southern region of the lake.

During all other sampling periods, conductivity gradients were not detected even though conductivities at the mouths of inflowing rivers (Cobb and Flannagan 1987) were generally higher than in the lake. This lack of an effect on conductivity was due to low river discharge and thorough mixing of lake water. Historically, conductivity data collected by Canada Department of the Environment (1978) from 1967 to 1976 at the Mossy River outlet of Dauphin Lake is similar to that measured in this study (Table 11).

Any gradients observed for major ions were similar to those for conductivity. Only isopleths of sodium (Na^+), sulphate ($SO_4^=$) and chloride (Cl^-) were plotted (Fig. 6, 7 and 8, respectively) since these showed the largest regional differences in the lake. The isopleths of major cations and anions in Lake Winnipeg were also similar to conductance distributions (Brunskill et al. 1979) but were much more distinct than those found in Dauphin Lake. This, again, is probably due to the well mixed nature of Dauphin Lake and relatively small influences from inflowing rivers. The relative abundance of major ions in Dauphin Lake is $Ca^{++}>Mg^{++}>Na^+>K^+$ and $HCO_3^-> SO_4^= > Cl^-$. These relative abundances are similar to Lake Winnipeg (Brunskill et al. 1979) and are generally characteristic of lakes of the temperate zone (Wetzel 1975). Lake Manitoba differed from these other lakes with relative abundance of $Na^+>Mg^{++}>Ca^{++}>K^+$ and $Cl^-> HCO_3^-> SO_4^=$ (Teller and Last 1979). Lake Manitoba differs considerably in that the residence time is relatively long and composition of ions in the water may be influenced to a greater extent by groundwater sources of different ionic composition.

Total suspended solids and suspended nutrients

Total suspended solids (T.S.S.) and the suspended nutrient elements (carbon (C), nitrogen (N) and phosphorus (P)) (Tables 8 and 10) showed similar patterns with decreasing gradients from the region of the Wilson and Vermilion rivers in May, June and September (Fig. 9-12, inclusive). Gradients in other areas of the lake and at other sampling times were either weak or not discernible. It is unlikely that the higher concentrations originated from the rivers since Cobb and Flannagan (1987) report relatively low T.S.S. levels (<40 $mg \cdot L^{-1}$ at points 50 m upstream from river mouths) at approximately the same time. The gradients may have been wind-induced. Although winds were not strong during the sampling periods, earlier winds may have caused seiches which created currents that may have resuspended bottom particles. These particles were likely made up of sediment and plant material. A decreasing gradient originating from the southeast region of the lake occurred in late August. This may also have been wind-induced or may have resulted from a spate in the Turtle River which occurred at this time (Can. Dep. Environ. 1983b). Gradients in other areas and at other times were weak or not discernible, once again indicating a well mixed lake. Figure 2D illustrates the influence of spring run-off, winds and/or seasonal river spates on T.S.S. values in the lake. Figures 2E-G show fluctuations in suspended C , N and P , respectively. The ratio of suspended C :N :P for Dauphin lake of approximately 100:10:1 was similar to surficial sedients of the lake (calculated from the overall mean values of C_O, N and P in Table 14).

Other characteristics

Other characteristics measured, namely soluble reactive silicon (S.R.Si.), iron (Fe^{++}), manganese (Mn^{++}), nitrate (NO_3-N), total dissolved nitrogen (T.D.N.), total dissolved phosphorus (T.D.P.), bicarbonate (HCO_3^-) and dissolved organic carbon (D.O.C.) showed no discernible gradients (Tables 8 and 10). Figures 2H-K show mean values throughout the sampling period for some of these data.

CORRELATIONS

Correlation coefficients (r) calculated or those physical and chemical characteristics measured in 1982 that would be expected to be inter-related are shown in Tables 12 and 13. In some cases unexpected correlations or unexpected lack of correlations were found. Because these can be due to small sample size or uniformity in values, the raw data (Tables 7-10) should be consulted when evaluating unusual correlations.

SEDIMENT ANALYSES

Particle size

There were two distinct areas of sediment in the lake: "offshore" and "inshore". The offshore area (stations >500 m from shore and >2 m deep) was uniformly clayey silt or silty clay and the inshore (stations <500 m from shore and <2m deep) was predominantly sand with a small proportion of clay (Table 14 and Fig. 13 and 14). Station 17 which was about 500 m from shore and 2.6 m deep did not fall into either category and had all sediment types found in both the in- and offshore stations.

Sediments <2 mm dia. at offshore stations

were more uniform in particle size composition than at inshore stations. The relatively high silt content at stations 3 and 4 compared to other offshore stations indicated a depositional basin. However, insufficient samples were taken to determine its extent. The more intensively sampled north and central areas of the lake did not appear to have a depositional basin and particle size composition wasuniform throughout these regions. The inshore stations in Dauphin Lake had varying proportions of silt and sand and usually contained very little clay. The large variability of sediments near the east shore was expected since the shoreline consists of a variety of substrate types ranging from boulders >1 m dia. to areas of clay-like particles. It is not known how far into the lake this diverse substrate extends but it is at least 500 m in some areas as indicated by the samples taken at station 17. The diversity of the substrate along the east shore may not be truly reflected by our data because of the limitations of the sampling equipment. The sampling gear was selected primarily for collecting benthic organisms. The Birge-Ekman grab was limited for use only in soft sediments and the pneumatic grab with a 1 m handle was restricted to sampling in shallow areas. During some sampling periods attempts to sample for benthos at station 17 had to be abandoned because suitable substrate for the Birge-Ekman grab could not be found and it was too deep for the pneumatic grab.

Particles >2 mm dia. were generally less than 1% (by weight) at offshore stations but were as high as 33.5% at station 17 (Table 15) and consisted mainly of clam shell fragments at offshore stations, detritus near river mouths and gravel near the east shore and the outflow at Mossy River.

Summary data for percent sand, silt and clay in offshore sediments of Dauphin Lake, Lake Manitoba (south basin) and Lake Winnipeg show that percent sand is low in offshore areas in all three lakes (Table 16). The percent silt and clay of Dauphin Lake falls between those found for Lake Manitoba (Teller and Last 1979) and Lake Winnipeg (Kushnir 1971). Silt and clay data obtained by Brunskill and Graham (1979) from Lake Winnipeg are not directly comparable since they used 2.0 µm (instead of 3.9 µm) to separate the two fractions.

Organic matter and nutrient elements

Organic content of Dauphin Lake sediments determined using chemical analyses and L.O.I. yielded similar results (Table 14). The average concentration of organic carbon at all stations sampled using chemical analyses was 1.55% (S.D. ± 1.22) and using L.O.I. (110 - 420°C) was 1.46% (S.D. ± 0.93). The mean organic content in offshore stations was 2.12%, somewhat higher than inshore stations which was 0.54%. The offshore value is similar to the 1.53% organic content found for Lake Winnipeg but is considerably lower than the 14.1% and 12.6% found by Teller and Last (1979) and Tudorancea et al. (1979) for the south basin of Lake Manitoba. The reason for the higher levels in Lake Manitoba may be due to its greater central basin and lower flushing rate.

The mean percent content of total carbon, inorganic carbon, nitrogen and phosphorus in sediments for the stations sampled was 5.46%, 3.90%, 0.15% and 0.05%, respectively and mean value for L.O.I. at 110-850°C was 19.30%. Concentrations were generally higher and less variable at offshore stations than at inshore stations, except for inorganic carbon (Table 14). Stations 17 and 18 showed considerable variation between "duplicate" samples removed from the same grab sample (Fig. 14, compare 17a and 17b, 18a and 18b) which was expected considering the diversity of sediment types.

In general, percent organic carbon, total nitrogen and total phosphorus in offshore sediments in Dauphin Lake were similar to Lake Winnipeg (Table 14). Inorganic carbon was higher in Dauphin Lake and may indicate a different mineral composition of sediments (e.g. dolomite) than that found in Lake Winnipeg (see Davies et al. 1962).

SUMMARY

Overall, Dauphin Lake appears to be a well mixed lake, both vertically and horizontally. Most regional differences during the open water season appear to be due to wind action, with inflowing rivers having some effect during spring run-off. Offshore sediments are uniformly clayey silt or silty clay with more diverse sediments, having a high sand content, occurring inshore. Dauphin Lake is considerably smaller in area and volume than Lake Manitoba or Lake Winnipeg but similar in water chemistry. Dauphin Lake sediments are higher in inorganic carbon than Lake Winnipeg and Lake Manitoba.Dauphin Lake waters and sediment particle sizes are generally more homogenous than Lake Winnipeg, probably a function of its greater susceptibiity to wind induced mixing.

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Table 1. Dates of ice-off and freeze-up for Dauphin Lake, 1979-1988 (J. Jastrebski, Dauphin Lake commercial fisherman, Rorketon, personal communication).

Year	Date ice free	Date ice covered
1979	May 27	Nov. 24*
1980	Apr. 28	Nov. 23
1981	Apr. 22	Nov. 21
1982	May 7	Nov. 13
1983	May 11	Nov. 26
1984	Apr. 25	Nov. 2
1985	Apr. 28	Nov. 11
1986	May 5	Nov. 11
1987	Apr. 20	Dec. 1
1988	Apr. 30	Nov. 16

* Initially froze Nov. 10, but ice broke up.

Table 2. Dates and stations for collections of physical and chemical data for water from Dauphin Lake, 1982.

Date	Stations Sampled
Feb. 23, 24	A-I, inclusive
May 26-28	1-21, inclusive
June 23-25	1-21, inclusive
Aug. 4, 5	1-21, inclusive
Aug. 31, Sept. 1	1-21, inclusive
Sept. 24, 25	1-21, inclusive
Oct. 19, 20	2, 3, 7, 8, 9

Table 3. Some estimates of method precision for synthetic standards and Canadian Shield water (errors expressed as relative standard deviation; n=6) (after Stainton et al. 1977).

Analysis	Synthetic Standards		Canadian Shield Water	
	Level	Method Error (±)	Level	Lab Error (±)
Dissolved inorganic carbon (D.I.C.) (automated)	-	-	168 μ moles.L^{-1}	2%
Dissolved organic carbon (D.O.C.) (automated)	-	-	600 μ moles.L^{-1}	2%
Particulate carbon (Susp. C.)	200 μg.L^{-1}	4%	1 000 μg.L^{-1}	3%
Particulate nitrogen (Susp. N.)	25 μg.L^{-1}	5%	140 μg.L^{-1}	4%
Particulate phosphorus (Susp. P.)	150 μg.L^{-1}	<1%	25 μg.L^{-1}	6%
Total dissolved phosphorus (T.D.P.)	-	-	20 μg.L^{-1}	13%
Total dissolved nitrogen (T.D.N.)	-	-	640 μg.L^{-1}	2%
Nitrate (NO_3-H) (automated)	-	-	300 μg.L^{-1}	<1%
Particulate solids (T.S.S.)	-	-	8 mg.L^{-1}	6%
Sulphate (SO_4=) (automated)	10.0 mg.L^{-1}	2%	-	-
Chloride (Cl^-) (automated)	10.0 mg.L^{-1}	2%	-	-
Manganese (Mn^{++})	1.0 mg.L^{-1}	1%	-	-
Iron (Fe^{++})	1.0 mg.L^{-1}	3%	0.52 mg.L^{-1}	6%
Magnesium (Mg^{++})	1.0 mg.L^{-1}	1%	0.80 mg.L^{-1}	2%
Calcium (Ca^{++})	1.0 mg.L^{-1}	<1%	2.5 mg.L^{-1}	<1%
Potassium (K^+)	5.0 mg.L^{-1}	3%	-	-
Sodium (Na^+)	1.0 mg.L^{-1}	2%	4.80 mg.L^{-1}	<1%
Silicon (S.R.Si.) (automated)	1.00 mg.L^{-1}	<1%	2.10 mg.L^{-1}	<1%
Soluble reactive phosphorus (S.R.P.) (automated)	250 μg.L^{-1}	<1%	-	-
Ammonia-nitrogen (NH_3-N) (automated)	-	-	600 μg.L^{-1}	2%

Table 4. Some morphometric calculations for Dauphin Lake.

Depth Stratum m	Stratum Area km^2	% of Total Area	Cumulative Area km^2	Cumulative Area %	Stratum Volume km^3	% of Total Volume	Cumulative Volume km^3	Cumulative Volume %
0.0-0.5	22.1	4.2	522.0	100.0	0.256	23.8	1.075	100.0
0.5-1.5	36.5	7.0	499.9	95.8	0.481	44.8	0.818	76.1
1.5-2.5	288.4	55.3	463.4	88.8	0.307	28.6	0.337	31.3
2.5-3.0	174.7	33.5	175.0	33.5	0.030	2.8	0.030	2.8
3.0-3.5	0.3	0.1	0.3	0.1	-	-	-	-

Table 5. Summary of morphometric data for Dauphin Lake, Lake Manitoba (south basin) and Lake Winnipeg (south basin).

Parameter	Dauphin Lake	Lake Manitoba (south basin)	Lake Winnipeg (south basin)
Surface area (A_0, km^2)	522.0	3 107.0	2 780.0
Volume (V, km^3)	1.1	14.1	27.0
Mean depth ($\bar{Z}$,m)	2.1	4.5	9.7
Maximum depth (Z_m,m)	3.5	6.3	14.0
Maximum length (ℓ, km)	42.0	105.0	93.0
Maximum breadth (b,km)	20.0	47.0	46.0
Shoreline (L, km)	119.0	392.0	349.0
Shoreline-area ($km \cdot km^{-2}$)	0.23	0.13	0.13
Development of shoreline ($D_L = \frac{L}{2\sqrt{\pi A_0}}$)	1.5	1.6	1.9
Development of volume ($D_V = \frac{3\bar{Z}}{Z_m}$)	1.8	2.1	2.1
$\frac{\bar{Z}}{Z_m}$	0.60	0.71	0.69
Relative depth ($Z_r = 50 Z_m \sqrt{\pi}(\sqrt{A_0})^{-1}$)	0.014	0.010	0.024
Source	This study	Teller and Last (1979)	Brunskill et al. (1980)

Table 6. Surface inflow and outflow of major rivers and streams (dam) for Dauphin Lake, 1982 (Data from Canada Department of the Environment 1983b).

Location	Month												Total Inflow (Outflow)
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	
Valley River	-	-	123	11 600	3 960	1 260	765	1 830	304	1 380	-	-	21 200
Turtle River	-	-	397	26 700	10 400	2 520	1 200	732	616	2 830	-	-	45 400
Wilson River	-	-	153	15 800	2 020	359	142	858	149	855	-	-	20 300
Vermilion River	-	-	379	19 100	4 560	877	499	812	164	3 250	-	-	29 600
Ochre River	-	-	103	14 300	5 830	1 830	806	564	458	4 040	-	-	27 900
Edwards Creek	-	-	159	10 500	4 380	765	146	109	20	2 410	-	-	18 500
Mink River	-	-	198	2 110	280	26	138	23	3	135	-	-	2 910
Total Inflow	-	-	1 512	100 110	31 430	7 637	3 696	4 928	1 714	14 900	-	-	166 000
Mossy River (outflow)	(21 400)	(17 500)	(8 520)	(9 710)	(40 700)	(10 600)	(6 160)	(2 530)	(799)	(731)	(1 030)	(11 700)	(131 000)

Table 7. Physical and chemical data, Dauphin Lake, February 23-24, 1982.

Station	Ice Thickness m	Station Depth m	Sampling Depth m	Chlor. $\mu g \cdot L^{-1}$	Temp. °C	Dissolved O_2 $mg \cdot L^{-1}$ (% saturation)	pH	Conductivity $\mu S \cdot cm^{-1}$
A	0.79	2.4	0.0	-	0.2	-	8.25	740
			1.0	0.3	0.5	-		
			2.0	1.0	3.2	17.6 (131.3)		
B	0.85	2.7	0.0	-	0.9	-	8.03	700
			1.0	0.2	0.9	15.7 (109.8)		
			2.0	0.3	3.0	16.9 (125.2)		
			2.5	-	3.9	-		
C	0.81	2.7	0.0	-	0.9	-	8.19	730
			1.0	0.1	1.0	17.6 (123.1)		
			2.0	0.3	3.4	-		
			2.5	-	3.9	-		
D	0.87	2.0	0.0	-	1.0	-	8.16	700
			1.0	0.3	1.8	17.2 (123.7)		
			1.5	-	3.4	-		
			2.0	0.5	3.5	17.5 (131.6)		
E	0.79	2.5	0.0	-	0.9	-	8.26	710
			1.0	0.2	0.9	20.3 (142.0)		
			1.5	-	2.9	-		
			2.0	0.2	3.4	19.7 (147.0)		
			2.5	-	3.8	-		
F	0.94	2.2	0.0	-	1.0	-	8.22	710
			1.0	0.3	1.9	18.2 (130.9)		
			1.5	-	3.1	-		
			2.0	2.0	4.0	20.3 (155.0)		
G	0.96	2.0	0.0	-	1.3	-	8.17	740
			1.0	0.4	1.9	20.5 (147.5)		
			1.5	-	3.9	-		
			2.0	0.7	4.0	21.3 (162.6)		
H	0.83	1.8	0.0	-	0.9	-	8.16	740
			1.0	0.2	1.9	19.7 (141.7)		
			1.5	0.9	3.0	18.8 (139.3)		
I	0.95	2.0	0.0	-	1.0	-	8.17	770
			1.0	0.1	1.9	15.5 (111.5)		
			1.5	-	4.0	-		
			2.0	0.1	4.1	14.6 (111.5)		

Table 8. Chemical analyses of water samples from Dauphin Lake, February 23-24, 1982.

Station	S.R.Si.	Na^+	K^+	Ca^{++}	Mg^{++}	Fe^{++}	Mn^+	HCO_3^-	Cl^-	$SO_4^=$	T.S.S.	NO_3-N	T.D.N.	T.D.P.	Susp. P.	Susp. N.	Susp. C.	D.O.C.
	$mg \cdot L^{-1}$											$\mu g \cdot L^{-1}$						μ Mole $\cdot L^{-1}$
A	8.90	36.8	10.7	74.1	40.3	<0.02	<0.01	303.0	27.0	123.0	3	1 140	1 670	37	16	145	1 010	2 160
B	8.58	33.6	9.2	68.5	37.1	<0.02	<0.01	271.0	22.0	116.0	5	27	590	51	18	146	1 100	1 950
C	8.85	38.6	11.8	71.7	39.1	<0.02	0.01	282.2	30.0	121.0	6	77	640	52	28	188	1 350	1 590
D	7.72	37.1	11.5	68.5	38.9	<0.02	0.01	255.6	29.0	129.0	5	3 960	4 470	19	25	187	1 250	1 560
E	8.21	39.4	11.1	71.7	39.1	<0.02	<0.01	264.4	28.0	119.0	5	20	610	25	25	176	1 350	2 190
F	8.49	37.6	11.1	66.1	37.6	<0.02	0.01	271.0	26.0	120.0	5	48	540	43	30	174	1 170	1 930
G	8.40	40.2	10.3	74.1	42.1	<0.02	0.02	284.0	28.0	123.0	6	4	690	19	30	284	1 820	2 950
H	8.09	41.8	13.7	70.9	39.6	<0.02	0.02	282.8	25.0	123.0	7	3	620	26	41	353	2 300	2 270
I	7.75	38.9	9.9	73.5	41.8	<0.02	0.01	155.4	29.0	133.0	8	56	740	37	34	192	1 710	2 620

Table 9. Physical and chemical data, Dauphin Lake, 1982.

Station Number	Mean Station Depth m	Date	Secchi m	Sampling Depth m	Chlor. $\mu g \cdot L^{-1}$	Temp. °C	Dissolved O_2 (% saturation) $mg \cdot L^{-1}$	pH	Conductivity $\mu S \cdot cm^{-1}$
1	1.3	May 26	0.60	0.0	6.9	18.9	9.5 (103.3)	8.14	450
				0.5	7.2	18.6	9.5 (102.2)		
		June 11	0.15	0.0	7.4	16.0	9.8 (100.0)		
				0.5	8.3	16.0	9.8 (99.8)		
		June 24	0.21	0.0	10.9	18.8	8.8 (94.6)	8.19	490
				0.5	9.3	18.8	8.7 (93.5)		
		July 9	0.30	0.0	9.9	23.9	8.6 (102.4)		
				1.0	11.5	21.8	8.9 (102.3)		
		July 22	0.40	0.0	12.5	22.0	8.8 (101.0)		
				0.6	13.5	22.0	8.7 (100.0)		
		Aug. 4	0.28	0.0	15.5	22.8	8.6 (101.2)	8.37	470
				0.5	13.8	22.8	8.7 (102.0)		
		Aug. 17	0.45	0.0	-	21.9	8.7 (100.0)		
				0.8	11.4	21.9	9.1 (104.6)		
		Aug. 31	0.30	0.0	19.9	15.0	10.0 (100.0)	8.48	500
				1.0	17.1	14.8	9.8 (97.0)		
		Sept. 24	0.20	1.0	11.3	13.0	10.4 (99.0)	8.35	510
2	1.3	May 26	0.80	0.0	5.8	19.5	9.2 (101.1)	8.20	490
				0.5	4.1	19.4	9.1 (100.0)		
		June 11	0.15	0.0	8.2	16.1	10.0 (102.0)		
				1.0	9.1	16.2	9.9 (101.0)		
		June 24	0.10	0.0	10.2	18.5	8.7 (93.5)	8.22	490
				1.0	13.5	18.5	8.8 (94.6)		
		July 9	0.35	0.0	12.3	22.0	8.2 (94.3)		
				1.0	8.7	21.7	8.2 (94.3)		
		July 22	0.35	0.0	31.3	22.4	8.7 (101.2)		
				0.6	35.3	22.4	8.9 (103.5)		
		Aug. 4	0.28	0.0	13.7	22.9	8.7 (102.4)	8.37	490
				0.5	14.9	22.9	8.8 (103.3)		
		Aug. 17	0.45	0.0	10.6	23.2	9.0 (105.9)		
				0.8	10.6	23.1	9.0 (105.9)		
		Aug. 31	0.30	0.0	16.0	15.0	9.9 (99.0)	8.54	500
				0.8	11.4	15.0	9.8 (98.0)		
		Sept. 24	0.20	1.0	7.4	13.6	10.4 (100.0)	8.35	510
		Oct. 20	0.15	0.0	14.7	3.0	12.2 (90.4)	8.06	470
				1.0	13.0	3.0	12.3 (91.1)		
3	2.5	May 26	0.50	0.0	6.5	19.1	9.3 (101.1)	8.26	490
				1.0	5.6	18.9	9.5 (103.3)		
				1.8	5.7	18.9	9.2 (100.0)		
		June 11	0.15	0.0	8.5	16.0	9.9 (100.8)		
				1.0	7.4	15.9	10.1 (102.6)		
				1.8	7.8	15.8	9.9 (100.4)		
		June 25	0.22	0.0	8.0	18.1	8.8 (93.8)	8.28	500
				1.0	9.6	17.2	8.8 (92.1)		
				1.8	9.1	17.2	8.6 (90.0)		
		July 9	0.30	0.0	6.2	24.6	8.5 (103.2)		
				1.0	6.6	20.7	8.7 (97.8)		
				1.7	8.0	20.3	8.1 (90.3)		
		July 22	0.25	0.0	10.8	20.7	9.3 (104.5)		
				1.0	14.0	20.8	8.5 (95.7)		
				1.6	12.0	20.8	8.5 (95.7)		
		Aug. 4	0.30	0.0	11.9	23.3	9.2 (108.9)	8.42	470
				1.0	11.4	22.7	9.6 (112.3)		
				1.8	9.4	21.4	9.5 (108.3)		
		Aug. 17	0.40	0.0	14.1	21.9	9.1 (104.8)		
				1.0	12.1	21.6	9.1 (104.1)		
				1.8	14.9	20.4	8.8 (98.3)		
		Aug. 31	0.20	0.0	20.1	14.8	10.4 (103.2)		
				1.0	30.0	14.8	10.1 (100.2)	8.50	460
				1.8	31.0	15.0	9.9 (98.7)		
		Sept. 24	0.20	0.0	10.1	14.5	10.3 (101.4)	8.37	500
				1.0	14.1	14.0	10.5 (102.3)		

Table 9. continued

Station Number	Mean Station Depth m	Date	Secchi m	Sampling Depth m	Chlor. µg·L⁻¹	Temp. °C	Dissolved O_2 (% saturation) mg·L⁻¹	pH	Conductivity µS·cm⁻¹
3(cont.)	2.5	Sept. 24	0.20	1.6	14.1	12.9	10.2 (97.0)		
		Oct. 20	-	0.0	16.3	3.0	12.4 (91.9)	8.08	480
				0.5	-	3.5	12.4 (93.2)		
				1.7	11.1	3.8	12.5 (94.7)		
4	2.5	May 26	0.40	0.0	6.7	19.2	9.5 (103.6)	8.21	460
				1.0	7.0	18.9	9.7 (105.1)		
				1.8	6.4	18.3	9.4 (100.6)		
		June 11	0.20	0.0	10.2	15.4	9.9 (99.5)		
				1.0	9.8	15.4	10.0 (100.5)		
				1.8	9.9	15.5	10.0 (100.8)		
		June 25	0.22	0.0	9.0	18.0	8.8 (93.6)	8.25	460
				1.0	10.5	17.5	8.6 (90.5)		
				1.8	9.9	17.2	8.5 (88.9)		
		July 9	0.30	0.0	8.0	26.0	8.5 (106.0)		
				1.0	12.9	20.5	9.1 (101.9)		
				1.7	8.9	20.2	8.3 (92.4)		
		July 22	0.25	0.0	13.3	20.9	8.4 (94.8)		
				1.0	12.9	20.9	8.3 (93.7)		
				1.7	11.4	20.9	8.3 (93.7)		
		Aug. 4	0.30	0.0	12.5	23.3	9.1 (107.7)	8.42	460
				1.0	11.6	22.0	9.2 (106.1)		
				1.8	10.6	21.2	9.1 (103.3)		
		Aug. 17	0.25	0.0	7.5	22.1	9.0 (104.0)		
				1.0	12.0	22.0	9.0 (103.8)		
				1.6	11.7	20.6	8.2 (92.0)		
		Aug. 31	0.20	0.0	22.2	14.8	10.3 (102.2)	8.40	440
				1.0	22.6	14.8	10.0 (99.2)		
				1.6	24.9	14.8	10.1 (100.2)		
		Sept. 24	0.20	0.0	8.9	13.0	10.3 (98.1)	8.31	500
				1.0	9.7	13.0	10.1 (96.2)		
				1.6	14.1	12.8	10.0 (94.8)		
5	1.3	May 27	0.60	0.0	5.9	25.9	9.4 (116.9)	8.33	420
				0.5	7.3	24.8	9.3 (113.3)		
		June 11	0.25	0.0	8.2	17.8	10.0 (105.9)		
				1.0	7.8	17.5	10.0 (105.3)		
		June 25	0.23	0.0	9.5	18.2	8.8 (94.0)	8.27	480
				1.0	12.1	17.7	8.7 (92.0)		
		July 9	0.25	0.0	9.2	25.6	8.7 (107.7)		
				1.0	7.5	21.0	8.7 (98.4)		
		July 22	0.25	0.0	19.4	20.6	7.7 (86.4)		
				0.5	22.8	20.6	7.7 (86.4)		
		Aug. 4	0.30	0.0	18.6	23.5	9.5 (112.8)	8.42	460
				1.0	14.7	21.7	9.5 (108.9)		
		Aug. 17	0.40	0.0	17.6	23.1	9.8 (115.6)		
				0.6	18.7	23.0	9.6 (112.9)		
		Aug. 31	0.20	0.0	20.0	15.8	9.7 (98.4)	8.62	470
				0.5	22.3	15.8	9.8 (99.4)		
		Sept. 24	0.25	0.0	10.8	13.8	10.4 (100.9)	8.35	510
				1.0	9.6	13.8	10.4 (100.9)		
6	2.6	May 27	1.00	0.0	2.7	23.5	11.4 (135.4)	8.30	410
				1.0	2.4	20.2	10.2 (113.6)		
				2.0	4.4	19.7	10.1 (111.2)		
		June 11	0.15	0.0	10.6	15.2	10.0 (100.1)		
				1.0	11.6	15.8	10.2 (103.4)		
				1.8	11.4	15.8	10.1 (102.4)		
		June 25	0.23	0.0	13.2	17.8	8.9 (94.3)	8.31	470
				1.0	13.3	17.7	8.8 (93.0)		
				1.8	13.6	17.6	8.8 (92.8)		
		July 9	0.35	0.0	10.8	24.5	8.7 (105.5)		

Table 9. continued

Station Number	Mean Station Depth m	Date	Secchi m	Sampling Depth m	Chlor. $\mu g \cdot L^{-1}$	Temp. °C	Dissolved O_2 (% saturation) $mg \cdot L^{-1}$	pH	Conductivity $\mu S \cdot cm^{-1}$
6(cont.)	2.6	July 9	0.35	1.0	9.5	20.7	9.0 (101.1)		
				1.8	10.2	20.6	8.5 (95.4)		
		July 22	0.25	0.0	15.9	21.0	8.1 (91.6)		
				1.0	17.8	21.0	8.3 (93.9)		
				1.7	17.2	21.0	8.1 (91.6)		
		Aug. 4	0.30	0.0	9.1	24.5	9.4 (113.9)	8.41	460
				1.0	15.6	22.2	9.6 (111.2)		
				1.8	10.3	21.0	8.9 (100.7)		
		Aug. 17	0.40	0.0	11.3	22.0	9.0 (103.8)		
				1.0	11.4	22.0	9.0 (103.8)		
				1.8	13.6	21.0	8.9 (100.7)		
		Sept. 1	0.20	0.0	24.3	14.8	9.9 (98.2)	8.50	470
				1.0	15.6	14.8	9.7 (96.2)		
				1.8	26.3	14.8	9.6 (95.2)		
		Sept. 25	-	0.0	20.8	12.8	10.1 (95.7)	8.28	500
				1.0	17.1	12.7	10.1 (95.6)		
				1.8	25.4	12.6	10.1 (95.3)		
7	1.0	May 28	0.10	0.0	7.3	19.0	9.7 (105.3)	8.17	480
				0.5	7.1	19.0	9.7 (105.3)		
		June 10	0.25	0.0	8.4	17.2	9.9 (103.6)		
				0.5	7.8	17.2	9.8 (102.5)		
		June 24	0.12	0.0	7.9	17.3	8.6 (90.1)	8.14	470
				0.5	8.6	17.3	8.6 (90.1)		
		July 9	0.45	0.0	5.1	20.7	8.4 (94.4)		
				0.5	6.2	20.6	8.4 (94.3)		
		July 21	0.40	0.0	13.0	24.3	9.4 (113.4)		
				0.6	11.8	24.3	9.4 (113.4)		
		Aug. 5	0.40	0.0	15.5	22.6	9.1 (106.3)	8.62	490
				0.5	21.2	22.5	8.8 (102.6)		
		Aug. 18	0.22	0.0	15.8	24.4	8.6 (104.0)		
				0.5	17.5	24.4	8.7 (105.2)		
		Sept. 1	0.30	0.0	13.3	13.5	9.3 (89.6)	8.50	510
				0.8	11.4	13.8	9.4 (91.2)		
		Sept. 25	0.25	0.0	22.5	12.7	10.1 (95.6)	8.27	510
				1.0	10.4	12.4	10.1 (94.8)		
		Oct. 19	0.15	0.0	15.5	3.9	12.4 (94.2)	8.10	470
				0.5	14.9	3.9	12.4 (94.2)		
8	2.5	May 28	0.35	0.0	6.4	18.1	9.8 (104.5)	8.20	470
				1.0	7.2	19.2	9.3 (101.4)		
				1.8	5.9	19.2	9.2 (100.3)		
		June 10	0.20	0.0	8.7	17.0	9.8 (102.0)		
				1.0	9.2	17.0	9.7 (100.9)		
				1.4	10.0	17.0	9.8 (102.0)		
		June 24	0.13	0.0	7.4	17.4	8.6 (90.3)	7.99	450
				1.0	8.3	17.4	8.5 (89.3)		
				1.7	8.1	17.4	8.4 (88.2)		
		July 9	0.30	0.0	7.3	20.3	8.3 (92.5)		
				1.0	7.5	20.2	8.2 (91.3)		
				1.8	7.7	20.2	8.3 (92.4)		
		July 21	0.44	0.0	9.3	24.5	9.7 (117.6)		
				1.0	8.3	22.6	9.6 (112.1)		
				1.8	7.8	21.7	9.3 (106.7)		
		Aug. 5	0.45	0.0	13.1	21.8	8.9 (102.3)	8.63	490
				1.0	15.4	21.8	8.8 (101.1)		
				1.8	12.8	21.8	8.8 (101.1)		
		Aug. 19	0.33	0.0	18.2	21.0	8.4 (95.0)		
				1.0	16.6	21.0	8.4 (95.0)		
				1.8	16.3	21.0	8.3 (93.9)		

Table 9. continued

Station Number	Mean Station Depth m	Date	Secchi m	Sampling Depth m	Chlor. µg·L⁻¹	Temp. °C	Dissolved O₂ (% saturation) mg·L⁻¹	pH	Conductivity µS·cm⁻¹
8(cont.)	2.5	Sept. 1	0.30	0.0	13.6	14.5	9.8 (96.6)	8.56	500
				0.5	7.4	14.5	9.7 (95.6)		
				1.5	15.8	14.0	9.7 (94.5)		
		Sept. 25	0.25	0.0	14.5	12.3	10.1 (94.7)	8.31	490
				1.0	16.4	12.2	10.0 (93.5)		
				1.7	10.3	12.2	10.0 (93.5)		
		Oct. 19	0.15	0.0	16.0	4.0	12.1 (92.2)	8.14	480
				1.0	15.5	4.2	12.1 (92.6)		
				2.3	17.9	5.0	12.0 (93.8)		
9	2.8	May 28	0.20	0.0	22.8	18.8	9.3 (100.5)	8.12	370
				1.0	9.5	18.8	9.5 (102.7)		
				2.0	8.4	18.8	9.5 (102.7)		
		June 11	0.15	0.0	8.7	16.7	9.8 (101.3)		
				1.0	8.9	16.7	10.2 (105.5)		
				2.0	8.1	16.7	10.0 (103.4)		
		June 24	0.11	0.0	7.1	17.0	8.6 (89.6)	8.18	440
				1.0	8.8	17.0	8.7 (90.5)		
				1.6	8.0	17.0	8.7 (90.5)		
		July 9	0.30	0.0	9.5	20.6	8.5 (95.4)		
				1.0	9.6	20.4	8.5 (95.0)		
				1.8	9.5	20.1	8.3 (92.2)		
		July 21	0.32	0.0	9.0	24.7	9.5 (115.6)		
				1.0	9.2	22.9	9.7 (113.8)		
				1.9	9.0	21.7	9.0 (103.2)		
		Aug. 5	0.50	0.0	23.3	21.6	9.0 (103.0)	8.64	480
				1.0	20.3	21.6	9.0 (103.0)		
				1.8	19.7	21.6	9.0 (103.0)		
		Aug. 19	0.20	0.0	15.1	21.1	8.4 (95.2)		
				1.0	16.4	21.1	8.4 (95.2)		
				1.9	13.8	21.1	8.4 (95.2)		
		Sept. 1	0.30	0.0	15.8	14.0	9.7 (94.5)	8.60	490
				1.0	18.8	14.0	9.7 (94.5)		
				1.9	20.5	13.8	9.5 (92.1)		
		Sept. 25	0.20	0.0	15.9	12.8	10.0 (94.8)	8.30	500
				1.0	12.8	12.8	10.0 (94.8)		
				1.9	19.4	12.8	10.0 (94.8)		
		Oct. 19	0.15	0.0	18.3	4.0	12.0 (91.4)	8.24	490
				1.0	18.9	4.3	11.8 (90.6)		
				1.9	13.6	4.3	12.1 (92.9)		
10	2.8	May 28	0.35	0.0	11.0	19.5	10.4 (114.0)	8.29	470
				1.0	29.1	19.5	9.4 (103.1)		
				2.0	8.9	19.5	9.2 (100.9)		
		June 11	0.24	0.0	11.0	17.1	9.8 (102.3)		
				1.0	29.1	17.1	9.9 (103.3)		
				2.0	8.9	17.1	9.9 (103.3)		
		June 24	0.13	0.0	16.6	17.2	8.6 (90.0)	8.18	450
				1.0	10.1	17.2	7.9 (82.6)		
				1.9	8.0	17.2	8.5 (88.9)		
		July 9	0.25	0.0	8.3	21.7	7.8 (89.4)		
				1.0	8.7	21.0	8.4 (95.0)		
				1.9	9.5	20.8	8.5 (95.7)		
		July 21	0.45	0.0	11.1	23.9	9.2 (110.2)		
				1.0	11.0	22.9	9.1 (106.2)		
				1.9	10.3	21.8	8.1 (93.1)		
		Aug. 5	0.45	0.0	12.4	21.2	8.6 (97.6)	8.63	450
				1.0	14.0	21.1	8.6 (97.5)		
				1.9	13.1	21.1	8.4 (95.2)		
		Aug. 19	0.20	0.0	19.3	21.1	8.3 (94.1)		
				1.0	12.0	21.3	8.2 (93.3)		
				1.9	13.7	21.3	8.2 (93.3)		

Table 9. continued

Station Number	Mean Station Depth m	Date	Secchi m	Sampling Depth m	Chlor. $\mu g \cdot L^{-1}$	Temp. °C	Dissolved O_2 (% saturation) $mg \cdot L^{-1}$	pH	Conductivity $\mu S \cdot cm^{-1}$
10(cont.)	2.8	Sept. 1	0.30	0.0	13.9	14.0	9.7 (94.5)	8.52	460
				1.0	13.6	13.8	9.8 (95.1)		
				1.8	14.0	13.8	9.7 (94.1)		
		Sept. 25	0.20	0.0	19.1	12.4	10.0 (93.9)	8.31	500
				1.0	16.1	12.4	10.0 (93.9)		
				1.8	18.8	12.6	10.0 (94.3)		
11	2.5	May 28	0.35	0.0	12.1	22.1	8.5 (98.3)	8.26	430
				1.0	10.5	22.1	8.6 (99.4)		
				1.5	9.9	22.1	8.6 (99.4)		
		June 11	0.24	0.0	12.5	17.7	10.6 (112.1)		
				1.0	13.3	17.7	9.6 (101.5)		
				1.8	12.3	17.7	9.7 (102.5)		
		June 24	0.17	0.0	13.1	17.2	8.6 (90.0)	8.27	480
				1.0	12.6	17.2	7.9 (82.6)		
				1.8	9.2	17.2	8.5 (88.9)		
		July 9	0.25	0.0	11.0	22.5	8.6 (100.2)		
				1.0	11.9	20.8	8.4 (94.6)		
				1.7	15.3	20.2	8.0 (89.1)		
		July 21	0.40	0.0	12.6	23.2	9.2 (108.7)		
				1.0	10.7	22.8	9.1 (106.7)		
				1.8	12.1	22.4	8.1 (94.2)		
		Aug. 5	0.40	0.0	12.1	22.2	8.8 (102.0)	8.56	440
				1.0	15.9	22.2	8.7 (100.8)		
				1.8	18.9	22.2	8.7 (100.8)		
		Aug. 18	0.25	0.0	18.1	24.3	8.7 (104.9)		
				1.0	16.1	24.0	8.7 (104.4)		
				1.6	17.6	22.8	8.8 (103.2)		
		Sept. 1	0.30	0.0	19.3	14.0	9.5 (92.6)	8.56	470
				1.0	-	14.0	9.4 (91.6)		
				1.9	19.1	14.0	9.5 (92.6)		
		Sept. 25	0.20	0.0	16.9	12.9	10.0 (95.1)	8.33	500
				1.0	18.3	12.9	9.9 (94.1)		
				1.7	19.5	12.8	10.0 (94.8)		
12	1.3	May 28	0.40	0.0	11.3	21.8	8.5 (97.7)	8.27	410
				0.5	10.6	21.8	8.9 (102.3)		
		June 11	0.24	0.0	9.3	19.0	10.0 (108.6)		
				0.5	9.2	19.0	10.0 (108.6)		
		June 24	0.22	0.0	9.8	18.3	8.7 (93.1)	8.32	490
				0.5	9.8	18.0	8.7 (92.6)		
		July 9	0.25	0.0	10.3	21.7	8.5 (97.5)		
				1.0	10.2	20.6	8.8 (98.8)		
		July 21	0.40	0.0	13.3	23.6	9.1 (108.3)		
				1.0	12.7	23.2	9.2 (108.7)		
		Aug. 5	0.35	0.0	15.6	22.7	9.0 (105.3)	8.59	450
				0.6	16.1	22.7	9.0 (105.3)		
		Aug. 18	0.29	0.0	17.4	26.8	9.2 (116.5)		
				0.6	18.1	24.5	9.6 (116.4)		
		Sept. 1	0.25	0.0	18.7	15.0	9.2 (91.7)	8.50	460
				0.5	35.3	15.0	9.6 (95.7)		
		Sept. 25	0.20	0.0	18.4	12.9	10.1 (96.0)	8.36	510
				1.0	17.5	12.9	10.2 (97.0)		
13	1.0	May 27	1.10	0.0	5.3	23.0	8.7 (102.4)	8.15	600
				1.0	5.2	22.8	8.6 (100.8)		
		June 10	0.30	0.0	6.1	15.7	10.0 (101.2)		
				0.5	6.8	15.7	9.6 (97.2)		
		June 23	0.34	0.0	4.6	20.1	8.0 (88.9)	8.29	500
				0.5	5.1	19.2	8.3 (90.5)		
		July 8	0.30	0.0	7.6	19.4	8.7 (95.3)		
				0.5	6.8	19.1	8.6 (93.6)		

Table 9. continued

Station Number	Mean Station Depth m	Date	Secchi m	Sampling Depth m	Chlor. $\mu g \cdot L^{-1}$	Temp. °C	Dissolved O_2 (% saturation) $mg \cdot L^{-1}$	pH	Conductivity $\mu S \cdot cm^{-1}$
13(cont.)	1.0	July 21	0.33	0.0	7.9	21.8	8.8 (101.1)		
				0.5	7.4	21.0	8.9 (100.7)		
		Aug. 5	0.45	0.0	11.5	21.4	9.0 (102.6)	8.54	470
				0.5	9.6	21.4	9.1 (103.8)		
		Aug. 18	0.35	0.0	14.1	22.9	8.9 (104.5)		
				0.5	13.8	22.8	9.0 (105.5)		
		Sept. 1	0.70	0.0	9.4	14.5	9.6 (94.6)	8.58	470
				0.5	7.8	14.5	9.9 (97.5)		
		Sept. 25	0.20	0.0	10.8	11.0	10.1 (91.8)	8.34	500
				1.0	14.4	11.0	10.1 (91.8)		
14	2.5	May 27	0.75	0.0	2.7	22.0	9.8 (113.0)	8.19	470
				1.0	2.7	20.8	9.2 (103.6)		
				1.7	2.9	20.5	9.3 (104.1)		
		June 10	0.33	0.0	6.9	16.2	9.9 (101.3)		
				1.0	7.9	16.2	9.9 (101.3)		
				1.8	7.6	16.2	9.5 (97.2)		
		June 23	0.25	0.0	5.3	18.8	8.5 (91.9)	8.25	420
				1.0	6.3	18.6	8.4 (90.4)		
				1.8	5.9	18.6	8.4 (90.4)		
		July 8	0.33	0.0	6.5	20.2	8.2 (91.3)		
				1.0	7.2	20.1	8.2 (91.1)		
				1.8	6.6	20.0	8.1 (89.8)		
		July 21	0.34	0.0	6.0	21.9	9.0 (103.7)		
				1.0	6.8	21.5	9.1 (104.0)		
				1.8	7.4	21.2	8.8 (99.9)		
		Aug. 5	0.40	0.0	19.8	22.6	8.9 (104.0)	8.57	470
				1.0	19.1	22.1	8.3 (96.0)		
				1.8	20.1	21.8	8.7 (100.0)		
		Aug. 18	0.30	0.0	18.1	23.0	8.7 (102.4)		
				1.0	17.6	22.8	8.7 (102.0)		
				1.8	17.7	22.8	8.7 (102.0)		
		Sept. 1	0.30	0.0	8.9	14.5	9.2 (90.6)	8.52	500
				1.0	-	14.5	9.6 (94.6)		
				1.8	15.8	14.5	9.5 (93.6)		
		Sept. 25	0.25	0.0	15.8	12.0	10.1 (94.0)	8.32	480
				1.0	19.3	12.0	10.1 (94.0)		
				1.9	7.0	12.0	10.0 (93.0)		
15	3.0	May 27	0.85	0.0	2.6	22.0	9.6 (110.7)	8.22	470
				1.0	2.2	20.5	9.6 (107.5)		
				2.0	2.5	20.0	9.7 (107.5)		
		June 10	0.30	0.0	7.4	16.8	9.4 (97.4)		
				1.0	8.0	16.7	9.7 (100.3)		
				2.0	6.1	16.5	10.0 (103.0)		
		June 23	0.25	0.0	7.7	18.5	8.8 (94.6)	8.30	460
				1.0	7.6	18.1	8.8 (93.8)		
				2.0	7.3	17.9	8.8 (93.4)		
		July 8	0.20	0.0	6.7	20.5	8.4 (94.1)		
				1.0	7.2	20.2	8.5 (94.7)		
				2.0	8.4	20.1	8.4 (93.3)		
		July 21	0.33	0.0	7.7	22.0	8.8 (101.5)		
				1.0	7.5	21.7	9.2 (105.5)		
				2.0	7.7	21.4	8.7 (99.2)		
		Aug. 5	0.40	0.0	17.2	22.7	9.0 (105.3)	8.58	450
				1.0	18.1	22.3	9.0 (104.4)		
				2.0	15.0	21.8	8.6 (98.9)		
		Aug. 18	0.25	0.0	17.7	22.2	8.7 (100.8)		
				1.0	12.1	22.0	8.7 (100.3)		
				2.0	19.9	22.0	8.7 (100.3)		

Table 9. continued

Station Number	Mean Station Depth m	Date	Secchi m	Sampling Depth m	Chlor. µg·L⁻¹	Temp. °C	Dissolved O_2 (% saturation) mg·L⁻¹	pH	Conductivity µS·cm⁻¹
15(cont.)	3.0	Sept. 1	0.30	0.0	15.4	14.8	8.9 (88.3)	8.54	480
				1.0	13.9	14.8	9.9 (98.2)		
				2.0	15.9	14.8	9.7 (96.2)		
		Sept. 25	0.25	0.0	19.4	12.2	10.1 (94.4)	8.29	480
				1.0	19.6	12.2	10.0 (93.5)		
				1.9	9.4	12.2	10.0 (93.5)		
16	2.9	May 27	0.60	.0	5.5	23.5	9.5 (112.8)	8.18	320
				.0	5.0	21.2	9.5 (107.8)		
				2.0	4.6	20.1	9.9 (110.0)		
		June 10	0.30	0.0	9.0	17.5	9.5 (100.0)		
				1.0	8.5	17.2	9.9 (103.6)		
				2.0	9.8	16.9	9.8 (101.8)		
		June 23	0.25	0.0	9.2	19.5	8.6 (94.3)	8.33	490
				1.0	8.3	19.0	8.6 (93.4)		
				2.0	8.2	18.9	8.5 (92.1)		
		July 8	0.32	0.0	7.4	21.1	8.3 (94.1)		
				1.0	7.3	20.8	8.3 (93.5)		
				2.0	8.6	20.3	8.2 (91.4)		
		July 21	0.35	0.0	9.8	22.6	9.1 (106.3)		
				1.0	9.0	22.2	8.6 (99.7)		
				2.0	9.3	21.5	8.6 (98.3)		
		Aug. 5	0.40	0.0	14.9	22.8	8.5 (99.6)	8.50	440
				1.0	15.6	22.0	8.6 (99.2)		
				2.0	14.7	21.6	8.3 (95.0)		
		Aug. 18	0.22	0.0	18.7	22.9	8.5 (99.8)		
				1.0	17.3	22.5	8.5 (99.1)		
				1.9	8.8	22.2	8.5 (98.5)		
		Sept. 1	0.30	0.0	15.2	14.3	9.2 (90.3)	8.50	470
				1.0	16.4	14.3	9.3 (91.3)		
				2.0	11.4	14.3	9.4 (92.2)		
		Sept. 25	0.25	0.0	11.7	12.2	10.0 (93.5)	8.30	490
				1.0	18.5	12.2	10.0 (93.5)		
				1.9	15.8	12.2	9.9 (92.5)		
17	2.4	May 27	0.50	0.0	5.1	23.8	9.2 (109.9)	8.24	310
				1.0	5.5	21.6	10.2 (116.7)		
				1.5	6.5	20.9	9.5 (107.2)		
		June 10	0.33	0.0	8.2	17.5	9.7 (102.1)		
				1.0	8.3	17.5	9.8 (103.2)		
				1.8	7.7	17.5	9.8 (103.2)		
		June 23	0.30	0.0	8.0	19.7	8.8 (96.9)	8.34	490
				1.0	11.2	19.5	8.6 (94.3)		
				1.6	12.3	19.0	8.7 (94.5)		
		July 8	0.34	0.0	6.9	21.2	8.2 (93.1)		
				1.0	6.7	20.8	8.4 (94.6)		
				1.6	7.1	20.3	8.4 (93.6)		
		July 21	0.33	0.0	9.5	21.9	8.3 (95.6)		
				1.0	9.6	21.6	8.5 (97.3)		
				1.7	9.6	20.9	8.6 (97.1)		
		Aug. 5	0.40	0.0	20.9	23.7	9.3 (111.0)	8.56	450
				1.0	16.1	23.1	9.1 (107.3)		
				1.6	17.5	22.3	9.1 (105.6)		
		Aug. 18	0.22	0.0	20.1	24.7	8.5 (103.4)		
				1.0	13.1	22.8	8.6 (100.8)		
				1.9	16.6	22.5	8.4 (97.9)		
		Sept. 1	0.30	0.0	13.5	15.0	9.6 (95.7)	8.52	450
				1.0	20.2	15.0	9.5 (94.7)		
				1.7	12.5	15.0	9.4 (93.7)		
		Sept. 25	0.25	0.0	14.1	12.5	9.7 (91.3)	8.29	500
				1.0	10.6	12.5	9.8 (92.3)		
				1.6	13.3	12.5	9.6 (90.4)		

Table 9. continued

Station Number	Mean Station Depth m	Date	Secchi m	Sampling Depth m	Chlor. $\mu g \cdot L^{-1}$	Temp. °C	Dissolved O_2 (% saturation) $mg \cdot L^{-1}$	pH	Conductivity $\mu S \cdot cm^{-1}$
18	1.3	May 27	0.60	0.0	5.5	23.0	8.9 (104.7)	8.10	320
				1.0	6.7	22.3	9.3 (107.9)		
		June 10	0.33	0.0	8.5	17.8	9.5 (100.6)		
				1.0	9.0	17.8	9.6 (101.7)		
		June 23	0.33	0.0	11.1	20.1	9.0 (100.0)	8.32	490
				1.0	10.7	19.2	8.7 (94.9)		
		July 8	0.32	0.0	8.7	21.5	8.0 (91.4)		
				1.0	8.2	20.9	8.4 (94.8)		
		July 21	0.30	0.0	9.9	21.9	8.5 (97.9)		
				0.6	9.1	21.2	8.8 (99.9)		
		Aug. 5	0.40	0.0	25.6	24.8	9.4 (114.5)	8.57	440
				0.6	21.1	23.8	9.5 (113.5)		
		Aug. 18	0.22	0.0	17.6	25.8	8.5 (105.6)		
				0.7	23.9	23.6	8.4 (100.0)		
		Sept. 1	0.30	0.0	14.2	15.0	9.8 (97.7)	8.48	460
				0.5	17.3	15.0	9.8 (97.7)		
		Sept. 25	0.25	0.0	20.7	12.1	9.9 (92.4)	8.33	500
				1.0	16.7	12.1	10.0 (93.3)		
19	2.5	May 27	0.70	0.0	2.9	21.5	9.0 (102.9)	8.14	450
				1.0	2.8	20.8	9.0 (101.4)		
				1.5	2.9	20.2	9.0 (100.2)		
		June 10	0.25	0.0	5.5	17.0	9.5 (98.9)		
				1.0	7.2	17.0	9.8 (102.0)		
				1.8	8.0	16.9	9.5 (98.7)		
		June 23	0.25	0.0	6.7	19.7	8.3 (91.4)	8.21	420
				1.0	6.7	19.0	8.4 (91.2)		
				1.8	6.6	18.5	8.3 (89.2)		
		July 8	0.85	0.0	6.3	21.0	7.7 (87.1)		
				1.0	5.4	20.8	8.1 (91.2)		
				1.8	5.1	20.4	7.6 (84.9)		
		July 21	0.34	0.0	6.7	23.1	7.8 (92.0)		
				1.0	6.7	22.3	8.6 (99.8)		
				1.8	7.6	21.9	8.6 (99.1)		
		Aug. 5	0.40	0.0	24.1	24.1	9.5 (114.2)	8.59	450
				1.0	20.1	23.0	9.5 (111.8)		
				1.8	19.7	22.5	9.3 (108.4)		
		Aug. 18	0.23	0.0	21.4	24.8	9.3 (113.3)		
				1.0	21.4	23.0	9.1 (107.1)		
				1.8	21.5	22.6	8.6 (100.5)		
		Sept. 1	0.30	0.0	14.1	15.0	9.7 (96.7)	8.46	470
				1.0	16.6	15.0	10.0 (99.7)		
				1.8	17.6	15.0	10.0 (99.7)		
		Sept. 25	-	0.0	6.7	12.0	10.1 (94.0)	8.34	480
				1.0	9.3	12.0	10.1 (94.0)		
				1.6	10.9	11.9	10.1 (93.8)		
20	1.8	May 27	0.80	0.0	3.0	21.7	8.6 (98.6)	8.16	470
				1.0	3.0	20.2	9.8 (109.1)		
		June 10	0.33	0.0	8.1	17.5	9.7 (102.1)		
				1.0	4.6	17.3	9.9 (103.8)		
		June 23	0.22	0.0	5.7	20.1	8.4 (93.3)	8.21	410
				1.0	5.9	19.5	8.3 (91.0)		
		July 8	0.65	0.0	5.0	20.9	7.4 (83.5)		
				1.0	3.9	20.7	7.9 (88.8)		
		July 21	0.55	0.0	6.2	23.6	9.1 (108.3)		
				1.0	7.8	22.3	8.4 (97.4)		
		Aug. 5	0.40	0.0	12.0	23.9	9.3 (111.4)	8.56	440
				0.5	13.1	23.0	9.4 (110.6)		
		Aug. 18	0.33	0.0	20.4	24.8	9.1 (110.8)		
				1.0	16.3	24.8	9.2 (112.1)		
		Sept. 1	0.50	0.0	9.3	16.0	9.8 (99.8)	8.46	430
				0.5	9.9	16.0	9.6 (97.8)		
		Sept. 25	0.25	0.0	8.7	12.7	10.1 (95.6)	8.32	480
				1.0	6.2	12.5	10.1 (95.1)		

Table 9. continued

Station Number	Mean Station Depth m	Date	Secchi m	Sampling Depth m	Chlor. $\mu g \cdot L^{-1}$	Temp. °C	Dissolved O_2 (% saturation) $mg \cdot L^{-1}$	pH	Conductivity $\mu S \cdot cm^{-1}$
21	1.2	May 26	0.80	0.0	7.1	18.9	9.0 (97.5)	7.89	470
				0.5	8.0	18.6	9.1 (98.0)		
		June 11	0.20	0.0	7.7	16.2	9.7 (99.3)		
				0.5	6.8	16.2	9.8 (100.3)		
		June 24	0.10	0.0	7.2	19.5	8.5 (93.2)	8.29	500
				1.0	8.6	19.4	8.7 (95.3)		
		July 9	0.25	0.0	11.2	23.8	8.6 (102.7)		
				1.0	13.0	23.0	9.1 (107.1)		
		July 22	0.60	0.0	21.3	22.2	8.3 (96.2)		
				0.6	19.7	22.2	8.4 (97.3)		
		Aug. 4	0.27	0.0	14.8	22.7	9.0 (105.3)	8.46	480
				0.6	13.3	22.2	9.0 (104.3)		
		Aug. 17	0.50	0.0	12.5	23.1	9.0 (106.1)		
				0.6	11.4	23.0	8.9 (104.7)		
		Aug. 31	0.30	0.0	18.1	15.9	9.8 (97.7)	8.46	500
				0.5	18.0	15.0	- -		
		Sept. 24	0.20	0.0	-	15.5	10.0 (104.4)	8.16	500
				1.0	15.0	14.5	10.3 (101.5)		

Table 10. Chemical analyses of water samples from Dauphin Lake, 1982.

Station Number	Date	S.R.Si.	Na^+	K^+	Ca^{++}	Mg^{++}	Fe^{++}	Mn^{++}	HCO_3^-	Cl^-	$SO_4^=$	T.S.S.	NO_3^-N	T.D.N.	T.D.P.	Susp. P.	Susp. N.	Susp C.	D.O.C.
		mg·L^{-1}											μg·L^{-1}						μMole·L^{-1}
1	May 26	4.04	17.5	4.71	48.7	18.1	<0.04	0.01	176.1	12.0	70.0	11	2	670	16	27	120	1 110	950
	June 24	4.81	21.3	5.48	44.2	20.8	0.04	<0.01	190.3	17.0	83.0	95	18	580	35	81	245	2 750	1 050
	Aug. 4	5.55	22.3	5.65	38.5	23.3	0.03	<0.01	174.3	13.0	94.0	84	5	590	26	108	554	5 940	1 690
	Aug. 31	6.23	22.8	6.00	42.2	24.0	0.07	<0.01	189.7	18.0	80.0	81	3	570	43	97	564	5 590	760
	Sept. 24	5.18	25.2	6.09	50.6	24.9	0.09	0.02	188.0	14.0	89.0	65	1	550	39	82	316	3 810	980
2	May 26	4.82	16.4	4.31	54.2	20.8	<0.04	<0.01	210.5	12.0	70.0	9	3	560	23	22	66	830	950
	June 24	5.12	20.8	5.55	47.7	21.9	0.31	0.03	197.4	16.0	81.0	184	14	560	59	218	599	6 490	1 300
	Aug.4	5.98	22.0	5.81	42.0	23.3	0.03	<0.01	188.0	13.0	83.0	50	2	480	19	74	364	3 610	630
	Aug. 31	5.70	22.7	6.06	43.1	24.4	0.07	<0.01	188.0	17.0	79.0	44	2	530	42	63	235	3 100	840
	Sept. 24	5.47	24.5	5.91	49.6	24.4	0.06	<0.02	190.3	17.0	82.0	61	<1	510	58	77	353	3 360	700
	Oct. 20	5.65	20.2	4.99	46.5	22.0	0.06	<0.02	181.4	14.0	78.0	139	62	500	56	140	710	6 740	540
3	May 26	4.14	20.7	5.40	45.7	18.7	<0.04	<0.01	182.0	14.0	83.0	19	1	540	35	37	157	1 390	670
	June 25	5.12	21.3	5.46	50.2	22.1	0.04	0.01	189.7	17.0	85.0	52	1	630	37	58	204	2 240	770
	Aug. 4	5.26	20.3	5.55	41.9	22.3	0.03	<0.01	178.5	13.0	78.0	44	2	490	36	70	432	2 890	550
	Aug. 31	5.92	22.4	6.06	43.5	24.9	0.10	<0.01	192.1	17.0	80.0	142	2	470	53	160	809	8 340	700
	Sept. 24	5.80	22.0	5.36	47.8	22.1	0.09	<0.02	183.2	13.0	84.0	62	1	460	68	77	330	3 350	1 070
	Oct. 20	5.84	20.9	5.17	45.8	22.1	0.09	<0.02	182.0	15.0	78.0	113	30	590	66	116	569	5 700	550
4	May 26	4.03	19.7	5.02	42.3	19.8	0.04	0.01	173.7	14.0	77.0	28	<1	520	27	44	123	2 020	740
	June 25	4.70	19.1	5.14	41.2	19.0	0.04	<0.01	172.5	16.0	73.0	51	8	490	39	57	199	2 140	610
	Aug. 4	5.51	20.0	5.61	39.8	21.4	0.03	<0.01	177.3	12.0	76.0	44	2	480	39	65	396	3 130	590
	Aug. 31	5.96	20.5	5.79	41.6	23.4	0.07	<0.01	190.3	17.0	74.0	17	5	460	53	180	593	8 830	600
	Sept. 24	5.85	23.4	5.73	49.9	23.6	0.09	<0.02	185.6	15.0	87.0	65	<1	480	63	77	319	3 490	930
5	May 27	3.33	16.9	4.71	81.8	16.9	0.04	<0.01	161.3	13.0	64.0	18	42	620	31	38	166	1 470	740
	June 25	4.91	20.8	5.30	46.7	20.6	0.04	0.01	180.8	16.0	80.0	52	4	530	36	66	248	2 560	1 100
	Aug. 4	5.46	20.1	5.71	39.7	21.6	0.07	<0.01	177.3	12.0	74.0	46	3	480	35	74	408	2 860	570
	Aug. 31	6.14	22.1	5.96	40.8	23.5	0.07	<0.01	199.8	18.0	80.0	208	5	490	51	212	688	12 800	930
	Sept. 24	6.31	23.0	5.36	47.8	23.7	0.06	<0.02	185.0	15.0	88.0	42	<1	480	57	60	259	2 680	790
6	May 27	3.22	16.7	4.59	75.1	17.5	0.04	<0.01	150.6	12.0	64.0	10	52	560	24	29	117	1 050	630
	June 25	4.68	20.1	5.32	44.9	20.6	0.04	0.01	180.8	17.0	76.0	57	5	580	36	67	257	2 630	810
	Aug. 4	5.91	19.3	5.52	40.2	21.1	0.07	<0.01	178.5	12.0	74.0	43	2	490	35	65	375	2 200	640
	Sept. 1	5.94	20.7	5.81	42.0	22.1	0.10	<0.01	190.3	17.0	76.0	98	2	480	54	111	420	5 030	770
	Sept. 25	6.10	22.7	5.54	48.5	22.6	0.09	<0.02	193.9	15.0	86.0	150	<1	490	66	172	706	8 490	630
7	May 28	4.19	20.5	5.16	44.3	21.4	0.04	<0.01	178.5	14.0	79.0	163	86	580	33	170	438	7 300	700
	June 24	4.73	19.9	5.30	42.9	19.7	0.04	<0.01	181.4	18.0	77.0	363	36	510	45	332	930	13 140	630
	Aug. 5	5.64	21.8	5.83	39.8	23.6	<0.03	<0.01	175.5	13.0	82.0	40	2	540	20	70	417	2 870	620
	Sept. 1	5.28	22.8	5.89	43.8	24.0	0.03	<0.01	192.1	18.0	84.0	40	1	510	44	55	227	2 770	1 020
	Sept. 25	5.30	25.6	5.73	49.2	25.7	0.06	<0.02	202.8	16.0	88.0	245	1	470	46	274	978	13 360	700
	Oct. 19	5.59	20.8	5.17	45.8	21.7	0.09	<0.02	183.2	15.0	78.0	101	21	480	56	98	645	5 060	730

Table 10. continued

Station Number	Date	S.R.Si.	Na^+	K^+	Ca^{++}	Mg^{++}	Fe^{++}	Mn^{++}	HCO_3^-	Cl^-	$SO_4^=$	T.S.S.	NO_3^-N	T.O.N.	T.O.P.	Susp. P.	Susp. N.	Susp C.	D.O.C.
		$mg \cdot L^{-1}$											$\mu g \cdot L^{-1}$						$\mu Mole \cdot L^{-1}$
8	May 28	4.19	19.8	5.02	42.9	19.1	0.09	0.01	172.5	14.0	77.0	134	2	550	29	145	329	6 340	630
	June 24	4.54	19.0	5.00	41.6	19.5	0.09	0.01	179.1	17.0	71.0	311	7	480	40	278	852	12 120	820
	Aug. 5	5.35	21.3	5.75	42.4	24.6	0.03	<0.01	177.9	14.0	81.0	24	1	500	21	49	349	2 030	580
	Sept. 1	5.15	22.4	6.02	44.0	24.5	0.03	<0.01	186.0	16.0	83.0	42	1	500	38	62	319	3 060	1 310
	Sept. 25	6.05	22.2	5.36	47.8	22.6	0.09	<0.02	187.4	14.0	81.0	91	2	490	56	96	394	4 910	1 090
	Oct. 19	6.00	21.1	5.17	46.5	22.2	0.09	<0.02	184.4	15.0	78.0	97	11	370	63	100	837	4 950	490
9	May 28	3.29	16.0	4.35	72.0	13.7	0.04	<0.01	142.3	13.0	62.0	77	2	480	21	101	295	4 120	660
	June 24	4.52	18.0	4.98	41.6	17.6	0.09	<0.01	170.8	15.0	70.0	253	21	520	42	218	598	7 360	720
	Aug. 5	5.35	20.8	5.59	41.9	23.3	<0.03	<0.01	175.5	14.0	79.0	28	2	510	18	51	405	2 370	730
	Sept. 1	5.45	21.4	5.69	42.5	22.8	0.07	<0.01	187.4	17.0	80.0	57	<1	490	42	71	288	3 650	1 040
	Sept. 25	6.04	21.6	5.36	47.1	23.2	0.09	<0.02	189.1	15.0	81.0	103	<1	470	59	109	380	4 020	940
	Oct. 19	5.56	21.6	5.36	47.8	22.0	0.09	<0.02	190.9	15.0	81.0	99	21	440	66	102	-	5 530	580
10	May 28	4.05	20.2	5.00	43.5	18.6	0.04	<0.01	175.5	15.0	77.0	48	1	550	31	83	275	3 220	630
	June 24	4.81	18.9	5.16	43.7	18.3	0.09	0.01	182.6	16.0	71.0	237	28	550	43	220.	548	7 380	610
	Aug. 5	5.75	19.0	5.38	40.9	22.0	<0.03	<0.01	172.5	13.0	72.0	40	2	430	24	47	340	2 390	590
	Sept. 1	6.15	20.0	5.65	40.9	21.6	0.10	<0.01	188.0	16.0	75.0	84	7	480	48	92	291	-	1 120
	Sept. 25	6.15	22.0	5.54	49.2	22.9	0.25	<0.02	187.4	15.0	80.0	99	1	480	67	106	446	5 460	1 060
11	May 28	3.54	17.5	4.77	41.3	15.9	0.04	<0.01	163.1	13.0	63.0	42	16	570	23	74	283	2 900	630
	June 24	4.70	20.9	5.36	47.0	19.5	0.09	0.01	185.6	17.0	79.0	151	17	570	38	158	546	9 260	1 330
	Aug. 5	5.46	18.4	5.22	39.4	20.8	<0.03	<0.01	164.2	12.0	72.0	41	1	480	32	71	367	1 630	550
	Sept. 1	6.08	20.8	5.75	41.5	22.4	0.07	<0.01	188.5	16.0	76.0	105	3	490	47	113	431	6 100	700
	Sept. 25	6.19	23.4	5.91	49.9	24.2	0.09	<0.02	192.1	15.0	83.0	107	1	500	64	120	516	6 440	970
12	May 28	3.40	16.7	4.75	39.4	13.6	0.04	<0.01	155.9	14.0	62.0	34	12	500	26	56	252	2 300	620
	June 24	4.89	21.0	5.52	45.5	20.1	0.09	0.01	189.1	18.0	81.0	105	20	590	41	112	371	3 890	1 510
	Aug. 5	5.48	18.4	5.22	41.0	21.1	0.03	<0.01	166.0	12.0	70.0	50	1	480	26	82	432	3 460	560
	Sept. 1	6.13	20.2	5.48	40.2	21.3	0.03	<0.01	185.6	16.0	73.0	104	1	480	41	124	1242	6 460	730
	Sept. 25	6.18	23.2	5.54	49.9	23.5	0.06	<0.02	190.9	16.0	85.0	127	2	520	53	150	657	8 390	620
13	May 27	2.51	27.4	5.87	47.4	18.6	<0.04	<0.01	230.6	18.0	95.0	10	3	730	25	25	95	1 000	880
	June 23	3.48	21.0	5.34	46.9	20.3	0.04	<0.01	192.1	15.0	85.0	37	6	550	29	44	155	1 810	910
	Aug. 5	5.40	20.8	5.46	41.3	22.9	<0.03	<0.01	179.7	14.0	83.0	23	3	450	20	45	295	1 750	620
	Sept. 1	5.58	20.7	5.67	40.7	21.9	<0.03	<0.01	179.7	17.0	75.0	16	1	530	36	33	192	1 940	1 260
	Sept. 25	5.55	22.3	5.54	47.1	22.9	0.06	<0.02	191.5	15.0	82.0	107	<1	520	41	119	498	6 750	750
14	May 27	4.32	20.6	5.24	42.9	20.9	<0.04	0.01	174.3	16.0	75.0	11	6	540	20	29	114	1 020	650
	June 23	3.96	16.8	4.71	40.6	17.9	0.04	0.01	166.6	14.0	62.0	60	5	520	40	67	178	2 350	890
	Aug. 5	5.61	20.5	5.61	41.4	22.8	0.03	<0.01	176.1	15.0	79.0	28	2	520	22	56	364	2 160	600
	Sept. 1	5.45	21.9	5.87	42.0	23.1	0.03	<0.01	189.7	17.0	79.0	45	1	490	39	62	236	3 190	960
	Sept. 25	6.01	21.6	5.36	47.8	22.0	0.06	<0.02	179.7	15.0	78.0	50	1	460	56	67	338	3 350	900

Table 10. continued

Station Number	Date	S.R.Si.	Na^+	K^+	Ca^{++}	Mg^{++}	Fe^{++}	Mn^{++}	HCO_3^-	Cl^-	$SO_4^=$	T.S.S.	NO_3^-N	T.D.N.	T.D.P.	Susp. P.	Susp. N.	Susp C.	D.O.C.
		$mg \cdot L^{-1}$											$\mu g \cdot L^{-1}$						$\mu Mole \cdot L^{-1}$
15	May 27	4.17	20.5	4.94	42.9	21.8	<0.04	0.01	169.0	15.0	74.0	15	54	520	28	28	132	1 130	610
	June 25	4.55	19.3	5.28	42.1	18.6	0.04	0.01	179.1	15.0	71.0	71	4	580	46	73	222	2 600	1 260
	Aug. 5	5.56	18.5	5.26	38.9	20.5	<0.05	<0.01	168.4	14.0	71.0	28	<1	470	32	47	307	2 930	650
	Sept. 1	5.99	21.1	5.79	42.1	22.8	0.07	<0.01	186.2	17.0	76.0	46	1	510	44	56	-	2 950	920
	Sept. 25	6.18	21.3	5.36	47.1	21.8	0.06	<0.02	183.2	16.0	78.0	79	<1	500	56	90	363	4 380	1 590
16	May 27	2.59	12.6	4.04	31.9	13.0	<0.04	0.01	122.7	11.0	44.0	13	3	500	22	33	152	1 210	610
	June 25	4.86	20.4	5.28	44.0	19.8	0.04	<0.01	182.6	18.0	75.0	62	6	630	44	65	200	2 360	1 080
	Aug. 5	5.69	18.9	5.42	38.8	20.9	0.03	<0.01	167.2	13.0	70.0	33	3	440	35	48	298	1 990	630
	Sept. 1	5.98	20.4	5.55	41.7	22.5	0.03	<0.01	181.4	17.0	72.0	45	1	520	36	55	213	2 980	880
	Sept. 25	6.31	22.0	5.54	47.8	22.6	0.06	<0.02	186.8	16.0	80.0	72	<1	480	61	83	357	4 340	720
17	May 27	2.45	12.1	3.86	32.1	14.0	0.04	0.01	122.7	9.0	41.0	16	19	550	24	41	174	1 420	660
	June 25	4.91	20.8	5.28	44.9	19.8	0.04	0.01	185.8	18.0	77.0	48	4	630	41	58	205	2 430	1 090
	Aug. 5	5.65	18.4	5.34	41.3	21.1	<0.05	<0.01	166.0	13.0	75.0	29	2	550	29	57	375	2 170	610
	Sept. 1	5.98	20.0	5.53	39.0	21.1	0.03	<0.01	182.6	16.0	70.0	52	<1	550	39	67	206	3 880	1 070
	Sept. 25	6.27	22.7	5.54	48.5	23.5	0.06	<0.02	187.4	17.0	85.0	94	1	480	56	106	495	5 990	920
18	May 27	2.58	12.0	3.96	32.0	13.0	0.04	0.01	125.7	10.0	41.0	15	12	570	31	47	195	1 490	650
	June 25	4.92	20.8	5.22	44.2	19.8	0.04	0.01	185.0	19.0	76.0	40	2	510	33	53	203	2 020	1 880
	Aug. 5	5.47	18.7	5.40	38.4	21.9	<0.05	<0.01	164.8	14.0	71.0	36	1	560	19	72	426	3 030	780
	Sept. 1	5.92	20.1	5.63	39.6	21.0	0.03	<0.01	181.4	16.0	70.0	59	<1	510	31	74	309	4 390	1 330
	Sept. 25	6.26	22.5	5.54	46.5	22.5	0.06	<0.02	189.7	17.0	82.0	106	<1	540	54	120	526	5 820	970
19	May 27	3.84	19.6	5.14	39.8	20.9	<0.04	0.01	161.5	16.0	70.0	12	2	450	29	27	112	1 110	650
	June 25	3.76	16.8	4.81	40.2	15.9	0.04	0.01	164.2	14.0	58.0	52	5	560	36	56	217	2 970	1 010
	Aug. 5	5.61	19.3	5.42	40.1	21.4	<0.03	<0.01	169.0	14.0	74.0	30	1	510	25	56	358	2 240	590
	Sept. 1	5.90	20.4	5.59	40.2	21.6	0.03	<0.01	183.2	16.0	73.0	51	<1	500	43	64	248	3 370	1 110
	Sept. 25	5.59	22.9	5.73	47.8	23.0	0.03	<0.02	180.8	17.0	79.0	65	1	520	37	79	361	4 750	2 790
20	May 27	4.12	20.9	5.28	42.4	20.8	0.04	0.01	169.0	17.0	75.0	13	2	550	19	24	89	1 260	760
	June 25	4.01	16.7	4.77	39.6	16.0	0.04	0.01	165.4	14.0	58.0	71	4	490	29	77	257	340	940
	Aug. 5	5.01	19.0	5.34	38.6	20.9	<0.05	<0.01	160.7	14.0	71.0	18	1	510	21	41	265	1 810	620
	Sept. 1	4.85	21.1	5.65	37.9	21.6	<0.05	<0.01	176.7	16.0	73.0	22	<1	560	25	40	97	2 000	1 000
	Sept. 25	5.31	22.5	5.75	47.1	22.8	0.05	<0.02	182.0	16.0	77.0	83	13	520	32	94	408	4 260	1 040
21	May 26	4.27	19.1	5.00	46.0	20.7	<0.04	0.01	185.0	15.0	70.0	12	2	570	12	35	189	1 570	790
	June 24	5.19	21.2	5.52	45.2	19.8	0.18	0.01	200.4	17.0	77.0	147	6	580	45	155	548	7 340	900
	Aug. 4	5.67	22.0	5.81	42.0	24.3	0.03	<0.01	179.7	18.0	85.0	70	1	490	19	98	510	4 520	680
	Aug. 31	5.90	22.8	5.92	41.0	25.6	0.03	<0.01	192.7	18.0	82.0	75	1	550	38	91	432	5 650	1 090
	Sept. 24	5.21	24.3	6.09	47.1	26.4	0.09	<0.02	186.2	17.0	84.0	72	1	480	38	87	431	4 330	1 070

Table 11. A comparison of some physical and chemical data ranges of waters from three Manitoba lakes.

Parameter	Dauphin Lake	Dauphin Lake	Lake Manitoba (south basin)	Lake Winnipeg (south basin)	Lake Winnipeg (north basin)
Source	This study	Can. Dep. Environ. (1978)	Crowe (1972)	Brunskill et al. (1980)	Brunskill et al. (1980)
Years	1982	1961-1976	1966-1969	1968-1970	1968-1970
Secchi, m	0.10-1.10	-	-	0.05- 3.50	0.05-3.00
Chlorophyll, $\mu g.L^{-1}$	0.1 -35.3	<5.0-20.0	-	<1-57.1	<1-10.8
Dissolved O_2, $mg.L^{-1}$	6.4 -20.5	7.1-14.0	-	2.7 -13.3	6.8 -15.8
pH	7.89-8.64	7.9-8.6	7.61-9.21	7.00-8.76	7.39-8.80
Conductivity, $\mu S.cm^{-1}$	310-770	260-630	375-3 300	89-1 100	90-1720
Na^+, $mg.L^{-1}$	12.0-41.8	14.0-40.0	280-537	1.3-33.7	2.1-121.9
K^+, $mg.L^{-1}$	3.86-13.70	4.5-13.1	-	0.7-8.1	0.4-9.5
Ca^{++}, $mg.L^{-1}$	31.9-81.8	33.0-226.0	27.2-128.0	12.0-61.9	5.9-50.5
Mg^{++}, $mg.L^{-1}$	13.0-42.1	5.8-45.4	28.6-151.0	3.0-36.0	2.1-31.5
Cl^-, $mg.L^{-1}$	9.0-30.0	1.3-330.0	69-830	0.8-24.0	1.2-35.8
$SO_4^=$, $mg.L^{-1}$	41.0-133.0	60.0-185.0	48.5-332.0	4.0-103.0	1.0-68.0
Fe^{++}, $mg.L^{-1}$	<0.02-0.31	<0.01-0.05	0.08	-	-
Mn^{++}, $mg.L^{-1}$	<0.01-0.03	<0.01-0.05	-	-	-
S.R.Si., $mg.L^{-1}$	2.38-8.90	1.2-28.3	-	0.03-16.4	0.01-1.58
Susp. P., $\mu g.L^{-1}$	16-332	-	-	1-1 568	1-53
T.D.P., $\mu g.L^{-1}$	12-68	-	-	5-256	3-96
Susp. N., $\mu g.L^{-1}$	84-1 242	-	-	7-1 960	28-294
T.D.N., $\mu g.L^{-1}$	370-4 470	-	-	<1-1 176	140-854

Table 12. Correlation coefficients (r) for selected physical and chemical characteristics of Dauphin Lake water at each sampling period, 1982.

Characteristics	Sampling period					
	Feb. 22-23	May 26-28	June 23-25	Aug. 4-5	Aug. 31-Sept.1	Sept. 24-25
Secchi vs. Chlor.	-	-0.64*	-0.22	0.30	-0.70*	0.24
Secchi vs. T.S.S.	-	-0.72*	-0.81*	-0.75*	-0.64*	0.09
Chlor. vs. T.S.S.	-	0.37	0.14	-0.16	0.77*	0.65*
Chlor. vs. NO_3-N	-	-0.16	0.38	-0.12	0.65*	-0.27
Chlor. vs. T.D.N.	-	-0.16	0.18	0.48*	-0.41	-0.10
Chlor. vs. T.D.P.	-	-0.07	0.18	-0.30	0.79*	0.12
Chlor. vs. D.I.C.**	-	-0.14	0.28	-0.29	0.59*	0.43
Chlor. vs. D.O.C.	-	-0.11	0.14	0.47*	-0.36	0.19
Chlor. vs. Susp.P.	-	0.46*	0.17	0.00	0.77*	0.64*
Chlor. vs. Susp.N.	-	0.55*	0.14	0.17	0.63*	0.65*
Chlor. vs. Susp.C.	-	0.43	0.18	0.04	0.71*	0.64*
T.S.S. vs. Susp.P.	0.83*	0.99*	0.99*	0.94*	1.00*	0.99*
T.S.S. vs. Susp.N.	0.56	0.89*	0.97*	0.86*	0.68*	0.97*
T.S.S. vs. Susp.C.	0.77*	0.99*	0.94*	0.90*	0.90*	0.97*
Cond. vs. Na^+	0.52	0.94*	0.98*	0.89*	0.73*	0.69*
Cond. vs. K^+	0.02	0.89*	0.88*	0.68*	0.57*	0.29
Cond. vs. Ca^{++}	0.74*	0.11	0.84*	0.65*	0.70*	0.56*
Cond. vs. Mg^{++}	0.84*	0.77*	0.86*	0.88*	0.60*	0.75*
Cond. vs. Cl^-	0.36	0.81*	0.71*	0.30	0.54*	0.01
Cond. vs. SO_4=	0.59	0.96*	0.94*	0.76*	0.78*	0.83*
Cond. vs. D.I.C.**	0.85*	0.96*	0.90*	0.83*	0.43	0.63*
Susp.P. vs. Susp.N.	0.80*	0.95*	0.98*	0.92*	0.72*	0.98*
Susp.P. vs. Susp.C.	0.88*	1.00*	0.94*	0.86*	0.91*	0.98*
Susp.N. vs. Susp.C.	0.94*	0.93*	0.97*	0.83*	0.68*	0.99*

* significant at $p<0.05$

** at pH 8, HCO_3^- = 97.2% D.I.C.

Table 13. Correlation coefficients (r) for selected physical and chemical characteristics of Dauphin Lake water for each station, 1982.

Characteristics	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Secchi vs. Chlor.	-0.47*	-0.45*	-0.54*	-0.48*	-0.62*	-0.77*	0.54*	-0.04	0.68*	-0.79*	-0.32	-0.33	-0.42	-0.43	-0.69*	-0.54*	-0.28	-0.55*	-0.38	-0.47*	-0.30
Secchi vs. T.S.S.	-0.90*	-0.72*	-0.66*	-0.60*	-0.54*	-0.83*	-0.61*	-0.67*	-0.78*	-0.87*	-0.92*	-0.99*	-0.74*	-0.93*	-0.87*	-0.94*	-0.89*	-0.82*	-0.96*	-0.81*	-0.92*
Chlor. vs. T.S.S.	0.65*	0.07	0.94*	0.94*	0.71*	1.00*	-0.20	-0.66*	-0.89*	0.57*	0.43	0.43	0.37	0.10	0.46*	0.31	0.21	0.49*	0.17	-0.04	-0.06
Chlor. vs. NO_3^-N	-0.11	0.06	0.80*	0.33	-0.66*	-0.72*	-0.75*	0.15	-0.79*	0.31	-0.52	-0.93*	-0.71*	-0.76*	-0.81*	-0.43	-0.71*	-0.74*	-0.55*	0.00	-0.70*
Chlor. vs. T.D.N.	-0.59*	-0.42	-0.62*	-0.82*	-0.75*	-0.53*	-0.70*	-0.58*	-0.38	-0.03	-0.50	-0.63*	-0.72*	-0.47*	-0.61*	-0.36	-0.36	0.08	0.21	0.09	-0.62*
Chlor. vs. T.D.P.	0.65*	-0.12	0.36	0.40	0.33	0.99*	0.18	0.54*	-0.66*	0.92*	0.76*	0.45*	0.19	0.18	0.53*	0.30	0.16	-0.03	-0.25	0.14	0.13
Chlor. vs. D.I.C.**	0.28	-0.74*	0.49*	0.75*	0.72*	0.89*	0.72*	0.80*	-0.35	0.72*	0.79*	0.35	-0.64*	0.25	0.37	0.67*	0.45*	0.50*	0.46*	-0.03	-0.26
Chlor. vs. D.O.C.	0.61*	-0.21	-0.15	-0.49*	-0.20	0.73*	0.05	0.55*	-0.21	0.48*	0.04	-0.62*	-0.29	-0.19	0.45*	0.06	-0.24	-0.20	-0.23	-0.13	0.36
Chlor. vs. Susp.P.	0.82*	0.10	0.98*	0.96*	0.76*	0.98*	-0.09	-0.71*	-0.85*	0.52*	0.33	0.59*	0.49*	0.45*	0.61*	0.30	0.36	0.64*	0.61*	0.14	-0.01
Chlor. vs. Susp.N.	0.95*	0.23	1.00*	0.94*	0.91*	0.79*	0.28	0.00	-0.72*	0.81*	0.40	0.78*	0.76*	0.99*	0.99*	0.60*	0.65*	0.87*	0.96*	0.39	0.32
Chlor. vs. Susp.C.	0.91*	0.30	0.98*	0.96*	0.71*	1.00*	0.07	-0.66*	-0.87*	0.76*	0.40	0.79*	0.50*	0.47*	0.91*	0.45*	0.30	0.59*	0.32	0.41	0.20
T.S.S. vs. Susp.P.	0.90*	1.00*	0.99*	1.00*	1.00*	0.99*	0.99*	1.00*	1.00*	0.99*	0.99*	0.98*	0.99*	0.93*	0.98*	0.98*	0.98*	0.96*	0.88*	0.99*	0.99*
T.S.S. vs. Susp.N.	0.64*	0.90*	0.93*	0.97*	0.94*	0.83*	0.85*	0.67*	0.84*	0.92*	0.92*	0.55*	0.89*	0.24	0.60*	0.64*	0.68*	0.78*	0.37	0.80*	0.87*
T.S.S. vs. Susp.C.	0.69*	0.95*	0.99*	0.99*	1.00*	0.99*	0.95*	1.00*	0.98*	0.95*	0.99*	0.86*	0.98*	0.77	0.78*	0.86*	0.97*	0.95*	0.99*	0.37*	0.96*
Cond. vs. Na^+	0.89*	0.73*	0.01	0.79*	0.94*	0.98*	0.95*	0.95*	0.98*	1.00*	0.99*	0.97*	0.98*	0.98*	1.00*	0.99*	0.98*	0.99*	0.99*	0.85*	0.69*
Cond. vs. K^+	0.95*	0.48*	-0.74*	0.23	0.56*	0.95*	0.80*	0.80*	0.95*	0.37	0.89*	0.89*	0.46*	0.94*	0.45*	0.96*	0.95*	0.88*	0.89*	0.84*	0.52*
Cond. vs. Ca^{++}	0.11	0.03	0.89*	0.87*	-0.70*	-0.96*	0.30	0.49*	-0.84*	0.93*	0.89*	0.90*	0.67*	0.43	0.97*	0.94*	0.94*	0.96*	-0.08*	0.82*	-0.40
Cond. vs. Mg^{++}	0.81*	0.75*	-0.56*	0.27	0.85*	0.95*	0.88*	0.89*	0.97*	0.50*	0.76*	0.85*	-0.85*	0.93*	0.65*	0.92*	0.92*	0.90*	0.92*	0.77*	-0.03
Cond. vs. Cl^-	0.63*	0.72*	-0.18	-0.24	0.41	0.70*	0.21	-0.44*	0.64*	0.15	0.72*	0.63*	0.68*	0.85*	0.95*	0.89*	0.94*	0.94*	0.70*	0.70*	0.63*
Cond. vs. $SO_4^=$	0.45*	0.32	0.87*	0.92*	0.99*	1.00*	0.95*	0.99*	0.99*	0.96*	0.95*	1.00*	0.91*	0.93*	0.93*	0.99*	0.99*	0.99*	0.90*	0.85*	0.43
Cond. vs. D.I.C.**	0.85*	-0.46*	-0.12	0.03	0.65*	0.97*	0.78*	0.60*	0.98*	0.46*	0.95*	0.92*	1.00*	0.94*	0.60*	1.00*	0.97*	0.99*	0.72*	0.50*	0.81*
Susp.P. vs. Susp.N.	0.88*	0.91*	0.97*	0.90*	0.96*	0.89*	0.94*	0.91*	0.81*	0.83*	0.91*	0.60*	0.94*	0.56*	0.73*	0.73*	0.81*	0.92*	0.74*	0.86*	0.92*
Susp.P. vs. Susp.C.	0.93*	0.96*	1.00*	1.00*	1.00*	0.99*	0.98*	1.00*	0.99*	0.75*	0.99*	0.94*	0.99*	0.88*	0.88*	0.93*	0.98*	0.95*	0.94*	0.45*	0.96*
Susp.N. vs. Susp.C.	0.99*	0.98*	0.97*	0.91*	0.94*	0.81*	0.96*	0.91*	0.75*	0.89*	0.87*	0.67*	0.92*	0.60*	0.96*	0.77*	0.70*	0.84*	0.47*	0.59*	0.90*

* significant at $P<0.05$

** at pH8, HCO_3^- = 97.2 D.I.C.

Table 14. Percent dry weight (110°C) of total carbon (ΣC), carbonate (C_i), organic carbon (C_o) where $C_o = \Sigma C - C_i$, total nitrogen (ΣN) and total phosphorus (ΣP) determined by chemical analyses (Stainton et al. 1977) from surface sediment samples less than 2 mm in dia. from Dauphin Lake, September, 1983 and May 1984. Total % loss on ignition (L.O.I) at 850°C and % organic carbon (C_o) estimated from loss on ignition at 420°C (Teller and Last 1979) are also given. Lake Winnipeg and Lake Manitoba data are listed at the bottom of the table.

Station	ΣC % (μmoles·g^{-1})	C_i %	Co % (μmoles·g^{-1}) (chemical analyses)	ΣN % (μmoles·g^{-1})	ΣP % (μmoles·g^{-1})	Σ % wt L.O.I. 110-850°C	Co % (μmoles·g^{-1}) (L.O.I. at 420°C)
Inshore							
1*	5.30 (4 416.7)	4.40	0.90 (750.0)	0.03 (21.4)	0.05 (12.5)	19.11	0.61 (508.3)
2	-	-	-	-	-	-	-
5*	4.26 (3 550.0)	4.00	0.26 (216.7)	<0.01 (<7.1)	0.02 (5.0)	14.58	0.11 (91.7)
7	3.90 (3 250.0)	3.30	0.60 (500.0)	0.08 (57.1)	-	13.65	1.19 (991.7)
12	4.16 (3 458.3)	4.00	0.15 (125.0)	0.02 (14.3)	-	14.86	0.15 (125.0)
13	3.15 (2 625.0)	3.10	0.05 (41.7)	0.01 (7.1)	-	10.46	0.15 (125.0)
18a[1]	7.20 (6 000.0)	4.50	2.70 (2 250.0)	0.35 (250.0)	-	-	-
b[1]	6.05 (5 041.7)	5.80	0.25 (208.3)	0.03 (21.4)	-	-	-
c*	3.23 (2 691.7)	3.10	0.13 (108.3)	0.01 (7.1)	0.03 (7.5)	-	-
20a	6.10 (5 083.3)	5.90	0.20 (166.7)	0.03 (21.4)	0.03 (7.5)	17.14	0.29 (241.7)
b	3.94 (3 283.3)	3.80	0.14 (116.7)	<0.01 (<7.1)	-	-	-
Inshore $\bar{X}$	4.73 (3 940.0)(n=10)	4.19(n=10)	0.54 (448.3)(n=10)	0.06 (41.4)(n=10)	0.03 (8.1)(n=4	14.97(n=6)	0.42 (347.2)(n=6)
± S.D.	1.36 (1 133.9)	1.00	0.80 (668.8)	0.10 (74.8)	0.01 (3.2)	2.97	0.42 (347.2)
Offshore							
3*	5.36 (4 466.6)	3.60	1.76 (1 466.7)	0.18 (128.6)	0.08 (20.0)	20.02	2.26 (1 883.3)
4*	5.42 (4 516.7)	3.30	2.12 (1 766.7)	0.19 (135.7)	0.08 (20.0)	20.16	2.28 (1 900.0)
6	5.60 (4 666.7)	3.50	2.10 (1 750.0)	0.22 (157.1)	-	19.81	2.32 (1 933.3)
8	5.60 (4 666.7)	3.30	2.30 (1 916.7)	0.22 (157.1)	-	19.62	2.13 (1 775.0)
9	5.40 (4 500.0)	3.30	2.10 (1 750.0)	0.19 (135.7)	-	19.25	2.26 (1 883.3)
10	5.60 (4 666.7)	3.50	2.10 (1 750.0)	0.22 (157.1)	-	19.79	2.32 (1 933.3)
11	5.60 (4 666.7)	3.50	2.10 (1 750.0)	0.22 (157.1)	-	19.68	2.16 (1 800.0)
14	6.40 (5 333.3)	4.20	2.20 (1 833.3)	0.21 (150.0)	-	21.77	2.06 (1 716.7)
15	5.80 (4 833.3)	3.50	2.30 (1 916.7)	0.27 (192.9)	-	20.40	2.07 (1 725.0)
16	5.90 (4 916.7)	3.60	2.30 (1 916.7)	0.27 (192.9)	-	20.12	2.25 (1 875.0)
19	6.85 (5 708.3)	4.90	1.95 (1 625.0)	0.39 (278.6)	-	23.94	0.59 (491.7)
M	6.20 (5 166.7)	4.10	2.10 (1 750.0)	0.22 (157.1)	-	-	-

Table 14. continued

Station	ΣC % (μmoles·g^{-1})	C_i %	C_o % (μmoles·g^{-1}) (chemical analyses)	ΣN % (μmoles·g^{-1})	ΣP % (μmoles·g^{-1})	Σ % wt L.O.I. 110-850°C	C_o % (μmoles·g^{-1}) (L.O.I. at 420°C)
Offshore $\bar{X}$	5.81 (4 842.4)(n=12)	3.69(n=12)	2.12 (1 766.0)(n=12)	0.23 (166.7)(n=12)	0.08 (20.0)(n=2)	20.41(n=11)	2.06 (1 719.7)(n=11)
± S.D.	0.46 (380.1)	0.48	0.15 (129.1)	0.06 (40.5)	0.00 (0.0)	1.34	0.50 (414.6)
17a[1]	8.30 (6 916.7)	3.20	5.10 (4 250.0)	0.03 (21.4)	-	-	-
c	4.00 (3 333.3)	3.80	0.20 (166.7)	0.05 (35.7)	-	29.06	0.39 (325.0)
b[1]	7.10 (5 916.7)	4.40	2.70 (2 250.0)	0.34 (242.9)	-	23.32	2.23 (1 858.3)
c	4.00 (3 333.3)	3.80	0.20 (166.7)	0.05 (35.7)	-	29.06	0.39 (325.0)
Overall $\bar{X}$	5.46 (4 547.0)(n=25)	3.90(n=25)	1.55 (1 293.7)(n=25)	0.15 (108.6)(n=22)	0.05 (12.1)(n=6)	19.30(n=19)	1.46 (1 220.2)(n=19)
± S.D.	1.27 (1 057.8)	0.76	1.22 (1 019.7)	0.12 (87.8)	0.03 (6.6)	4.08	0.93 (776.8)
Lake Winnipeg (south basin) $\bar{X}$[3]	2.57 (2 140.0)(n=19)	1.04(n=19)	1.53 (1 276.0)(n=19)	0.14 (102.0)(n=19)	0.07 (23.0)(n=19)	12.36(n=19)[2]	1.97 (1 642.0)(n=3)
± S.D.	0.90 (745.9)	0.77	0.49 (409.2)	0.06 (39.1)	0.00 (2.5)	1.99	0.40 (333.0)
Lake Manitoba (south basin)	-	-	14.1 (range=6.7-30.4)[4] 12.6 (range-3.1-33.8)[5]	-	-	-	-

* collected May, 1984; others collected September, 1983.
[1] removed from same grab sample.
[2] ignition 100-900°C.
[3] data from Brunskill and Graham (1979).
[4] data from Teller and Last (1979)
[5] data from Tudorancea et al. (1979).

Table 15. Particle size distribution by weight of surface sediment samples from Dauphin Lake, Sept., 1983 and May, 1984.

Station	Depth m	% >2mm of total weight	% of Fraction <2mm SAND 2mm-63 µm	SILT 63 µm-4 µm	CLAY <4 µm
Inshore					
1	0.9	-	39.4	54.7	5.90
2	-	-	-	-	-
5*	1.0	-	97.4	0.5	2.1
7	0.9	3.0	56.7	23.9	19.4
12	1.3	1.3	73.9	24.3	1.8
13	1.1	-	73.9	24.1	1.9
18a[1,2]	1.2	-	2.4	77.4	20.2
b[1,2]	1.2	-	95.1	2.4	2.5
c*	1.2	-	97.7	0.4	1.9
20a[2]	1.5	-	95.5	2.1	2.4
b*	1.5	18.0	88.2	6.5	5.3
Inshore					
$\bar{X}$	1.2 (n=10)	7.4 (n=3)	72.0 (n=10)	21.6 (n=10)	6.3 (n=10)
±S.D.	0.2	9.2	31.3	26.0	7.2
Offshore					
3*	2.5	-	3.9	29.6	66.5
4*	2.5	-	4.0	31.2	64.8
6	2.7	0.1	3.8	55.8	40.4
8	2.8	0.2	4.7	52.8	42.5
9	2.9	0.2	5.1	55.3	39.6
10	2.8	-	4.7	50.0	45.3
11	2.9	-	3.9	62.3	33.8
14	2.7	-	8.9	63.9	27.2
15	3.0	-	6.6	54.7	38.7
16	3.0	-	4.3	49.0	46.7
19	2.6	-	8.1	60.2	31.7
M*	2.5	-	4.2	74.9	20.9
Offshore					
$\bar{X}$	2.7 (n=12)	0.2 (n=3)	5.2 (n=12)	53.3 (n=12)	41.5 (n=12)
±S.D.	0.2	0.1	1.7	12.8	13.5
17a[1]	2.6	-	38.3	43.5	18.2
b[1]	2.6	-	2.3	78.0	19.7
c	2.6	33.5	64.3	31.2	4.5
Overall $\bar{X}$	2.1 (n=25)	3.8 (n=6)	35.5 (n=25)	40.3 (n=25)	24.2 (n=25)
±S.D.	0.8	7.0	38.3	24.9	20.1

* collected May, 1984.
[1] removed from same grab sample.
[2] pneumatic grab sampler used.

Table 16. Percent particle size distribution (<2 mm) of offshore surface sediments of Dauphin Lake, Lake Manitoba (south basin) and Lake Winnipeg (south basin). The sand/silt boundary was 62.5 µm for all analyses and the silt/clay boundary was 3.9 µm, except in Brunskill and Graham (1979) where it was 2.0 µm.

Location	n	Depth m	% Sand ± S.D.	% Silt ± S.D.	% Clay ± S.D.	Source
Dauphin Lake	12	>2	5.2 ± 1.7	53.3 ± 12.8	41.5 ± 13.5	This study
Lake Manitoba (south basin)	39	>3	3.0 ± 3.4	70.3 ± 12.8	26.7 ± 14.4	Teller and Last (1979)
Lake Winnipeg (south basin)*	19	>4.5	0.1 ± 0.5	21.2 ± 15.6	76.6 ± 19.4	Kushnir (1971)
Lake Winnipeg (south basin)*	19	>4.5	3.6 ± 5.6	42.6 ± 18.2	37.6 ± 19.4	Brunskill and Graham (1979)

* data from two stations with high proportions of sand not included.

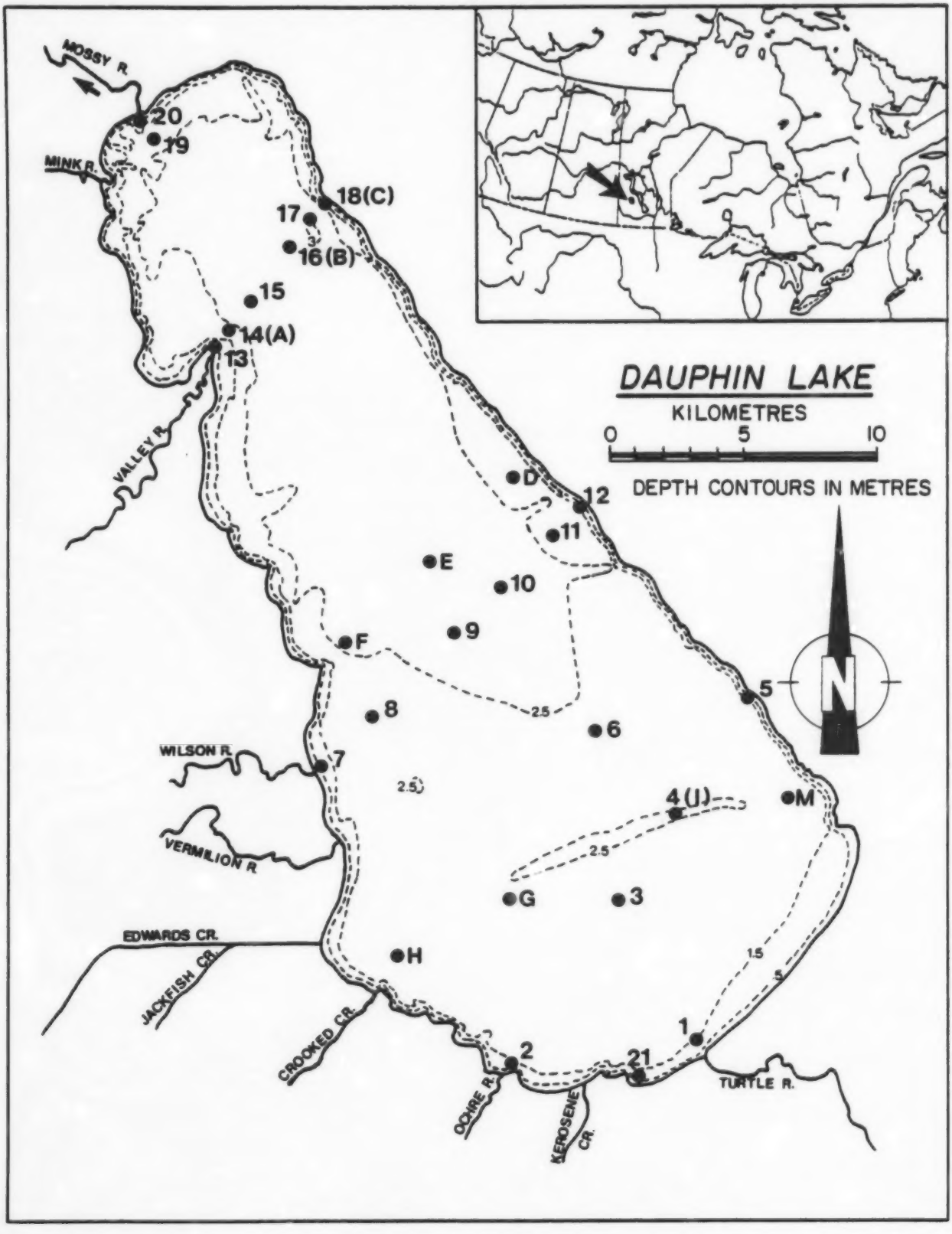

Fig. 1. Bathymetric map of Dauphin Lake showing water sampling stations, 1982 and sediment sampling stations, 1983 and 1984.

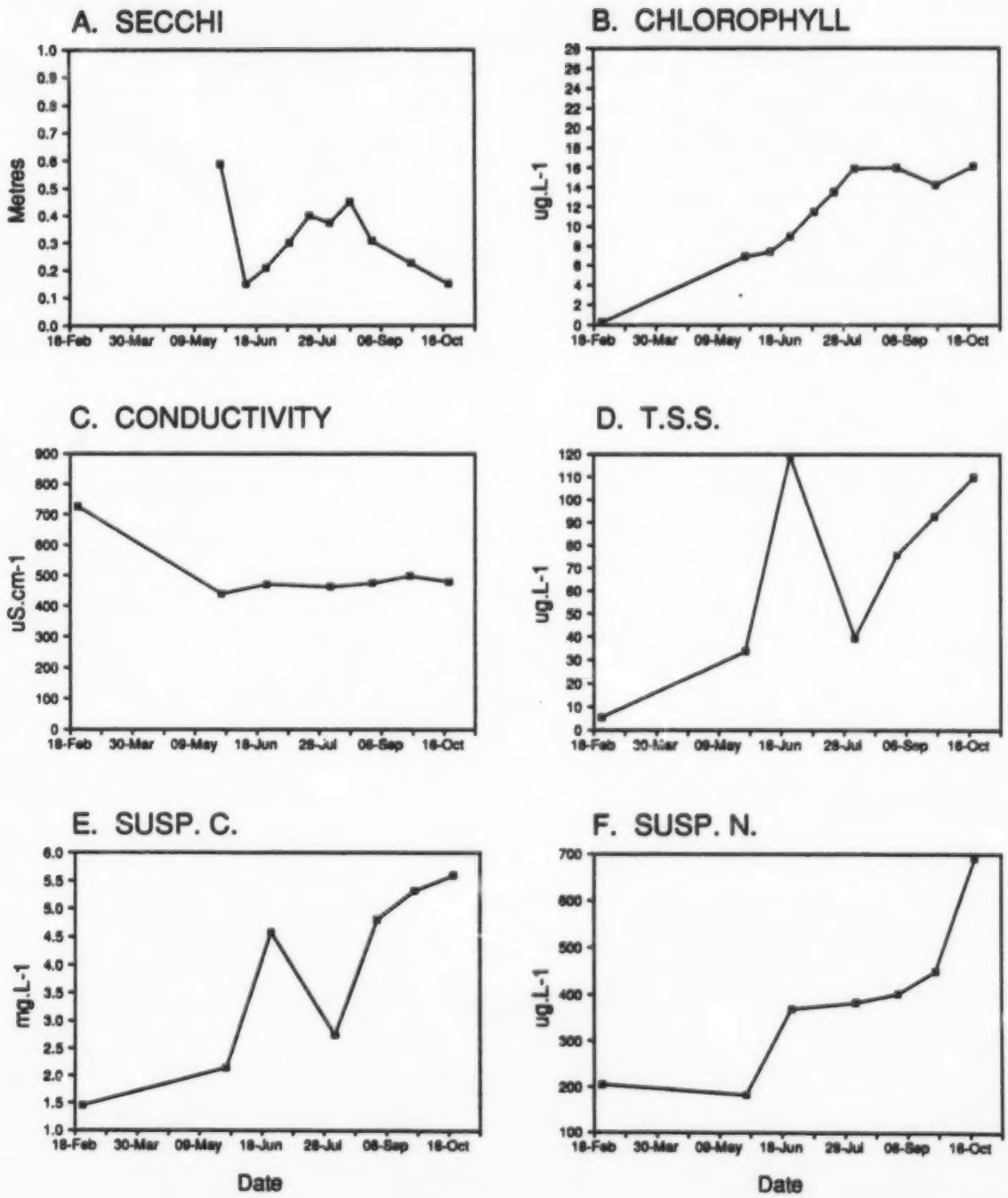

Fig. 2. Mean values of physical and chemical characteristics for all stations versus time, Dauphin Lake, 1982.

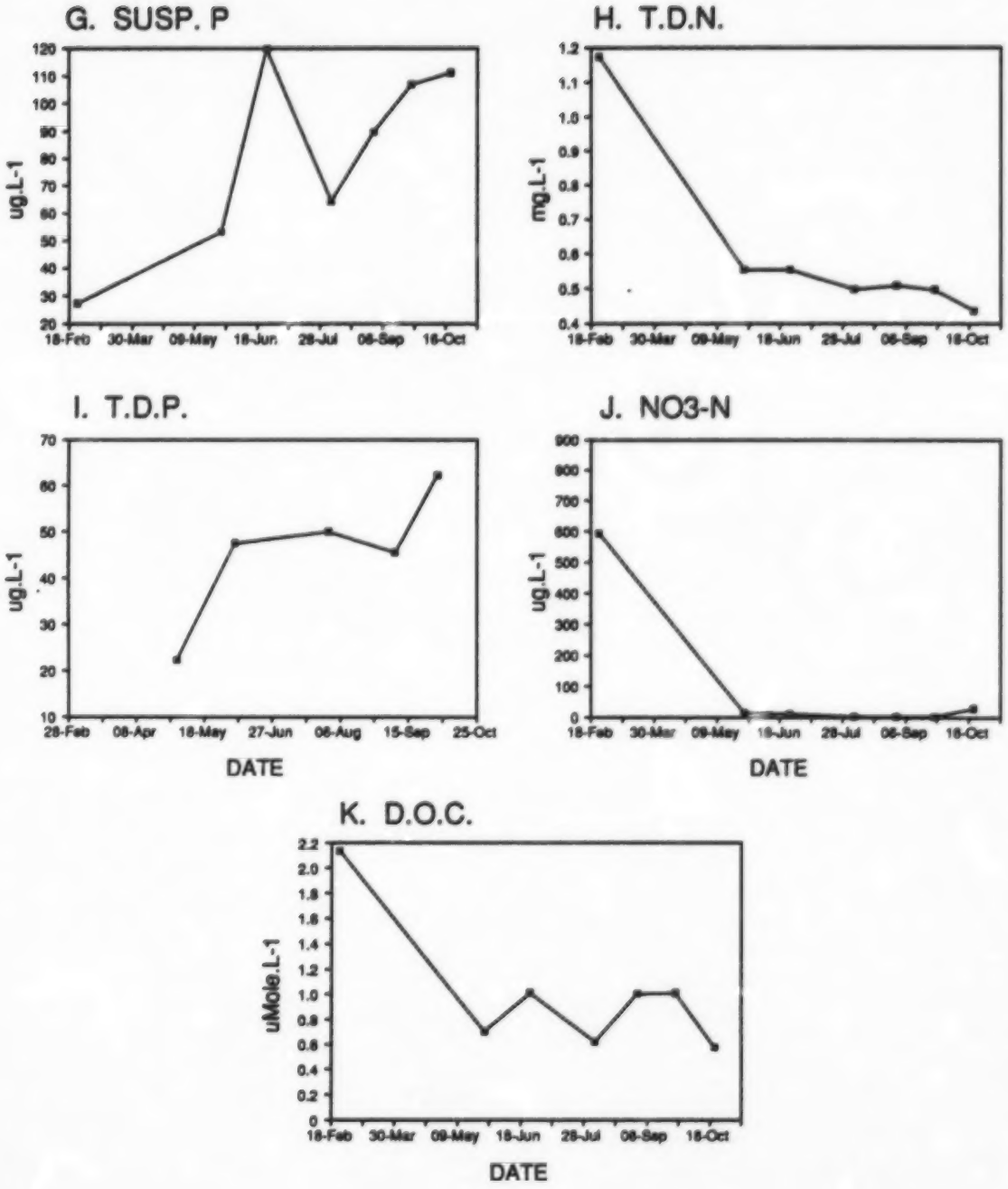

Fig. 2. continued

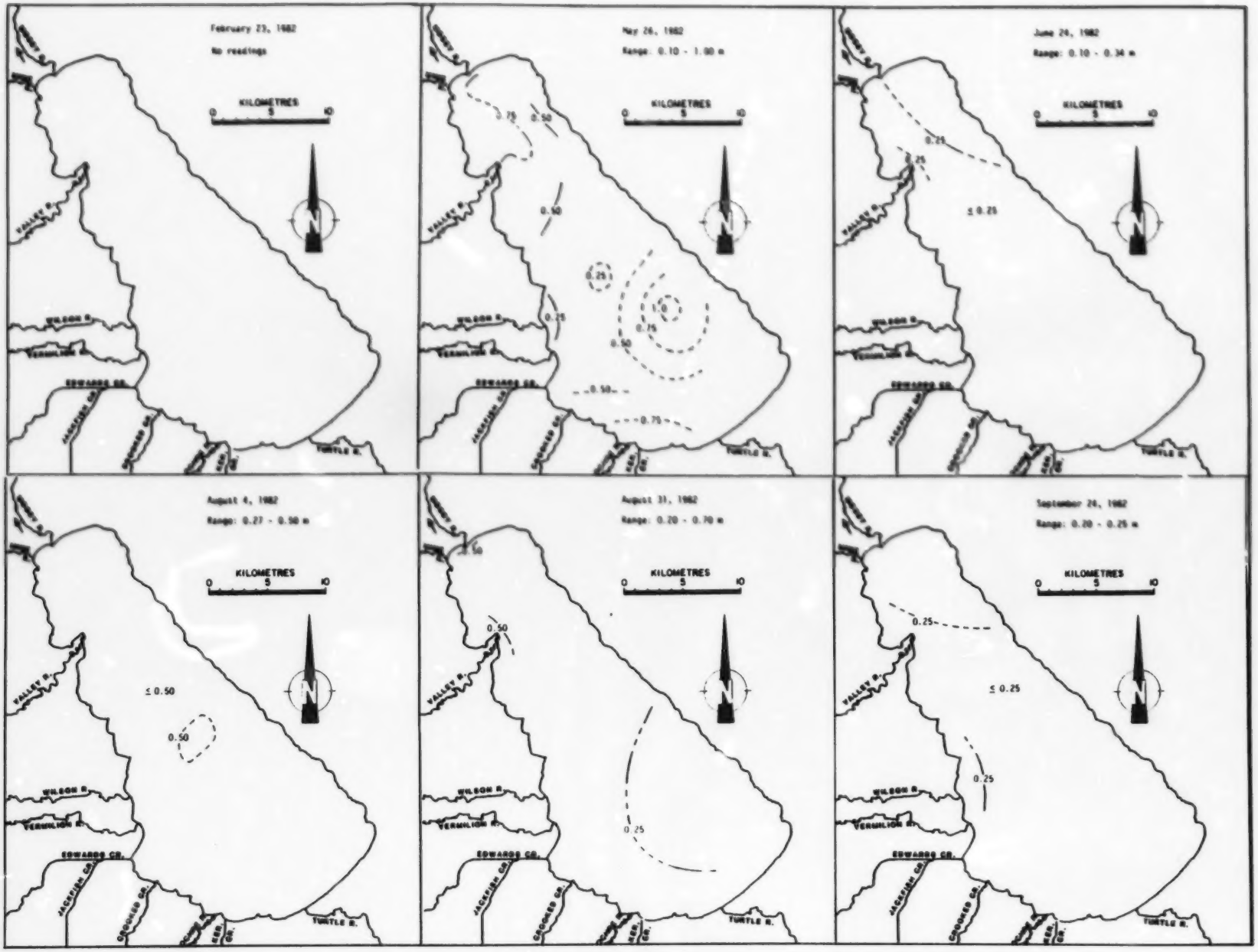

Fig. 3. Distribution of Secchi depths, Dauphin Lake, 1982. Isopleths are in 0.25m intervals.

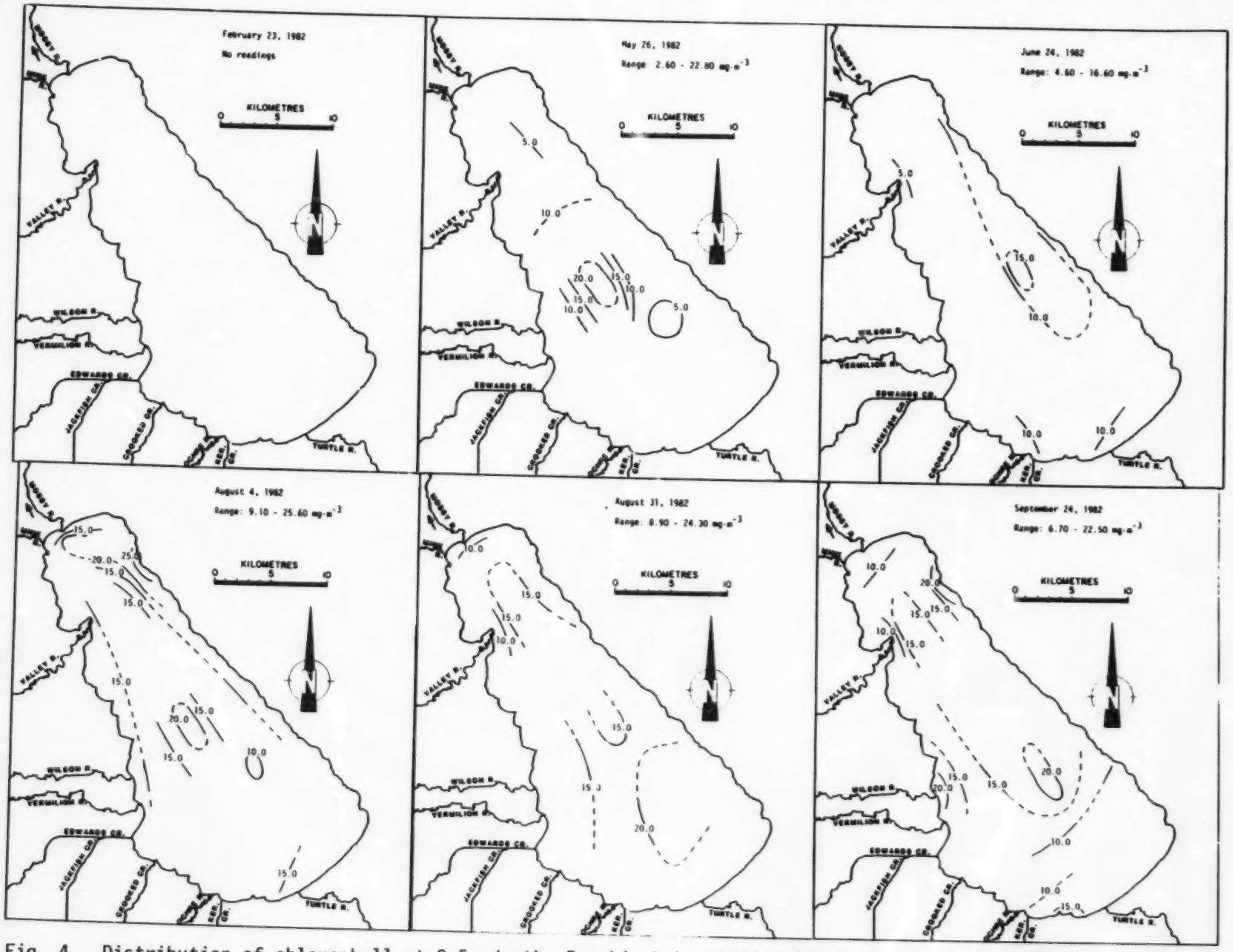

Fig. 4. Distribution of chlorophyll at 0.5m depth, Dauphin Lake, 1982. Isopleths are in 5.0 mg.m^{-3} intervals.

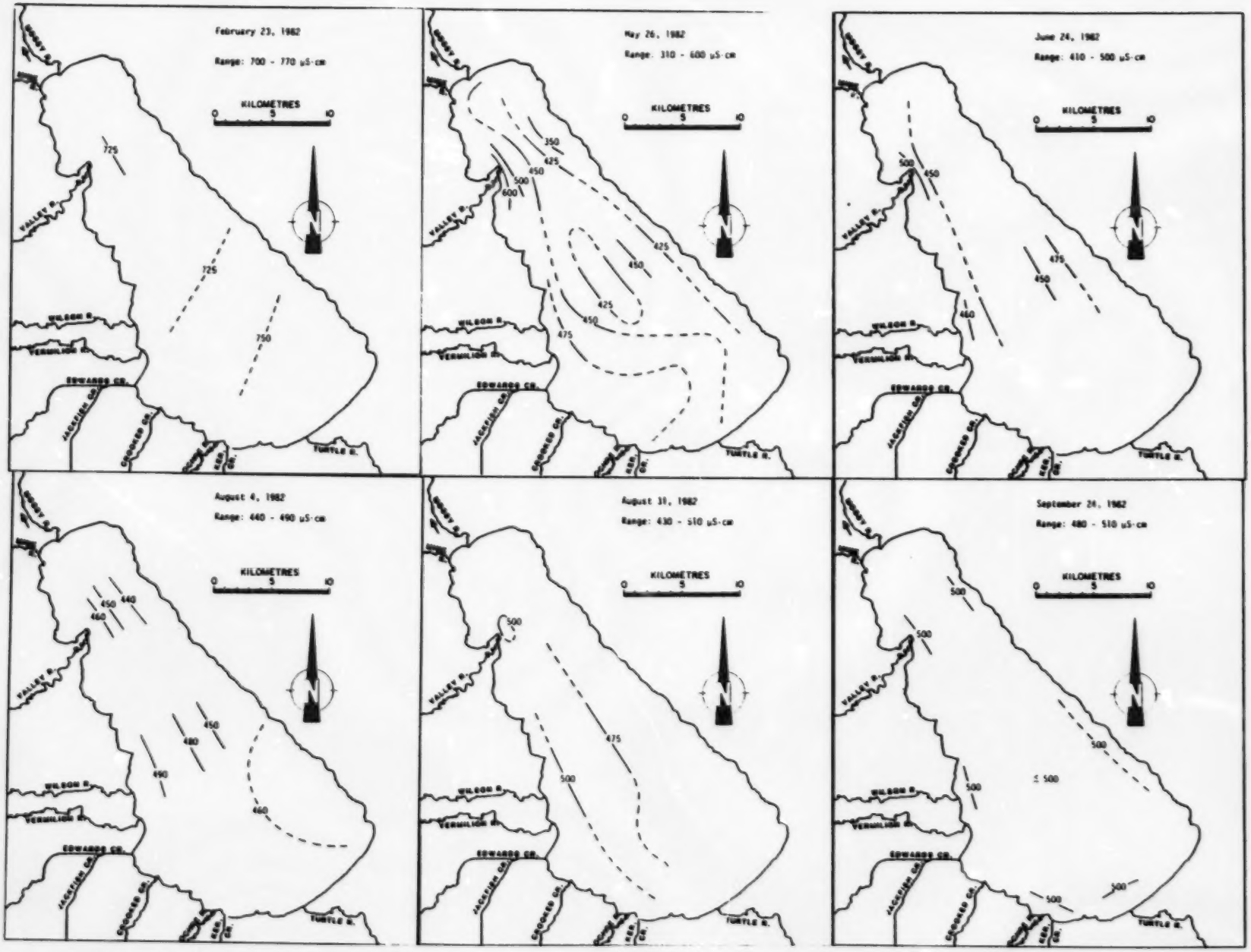

Fig. 5. Distribution of specific conductance, Dauphin Lake, 1982. Isopleths are in 350,425,440,460,475,480,490, 500,600,725 and 750 µS·cm^{-1} intervals.

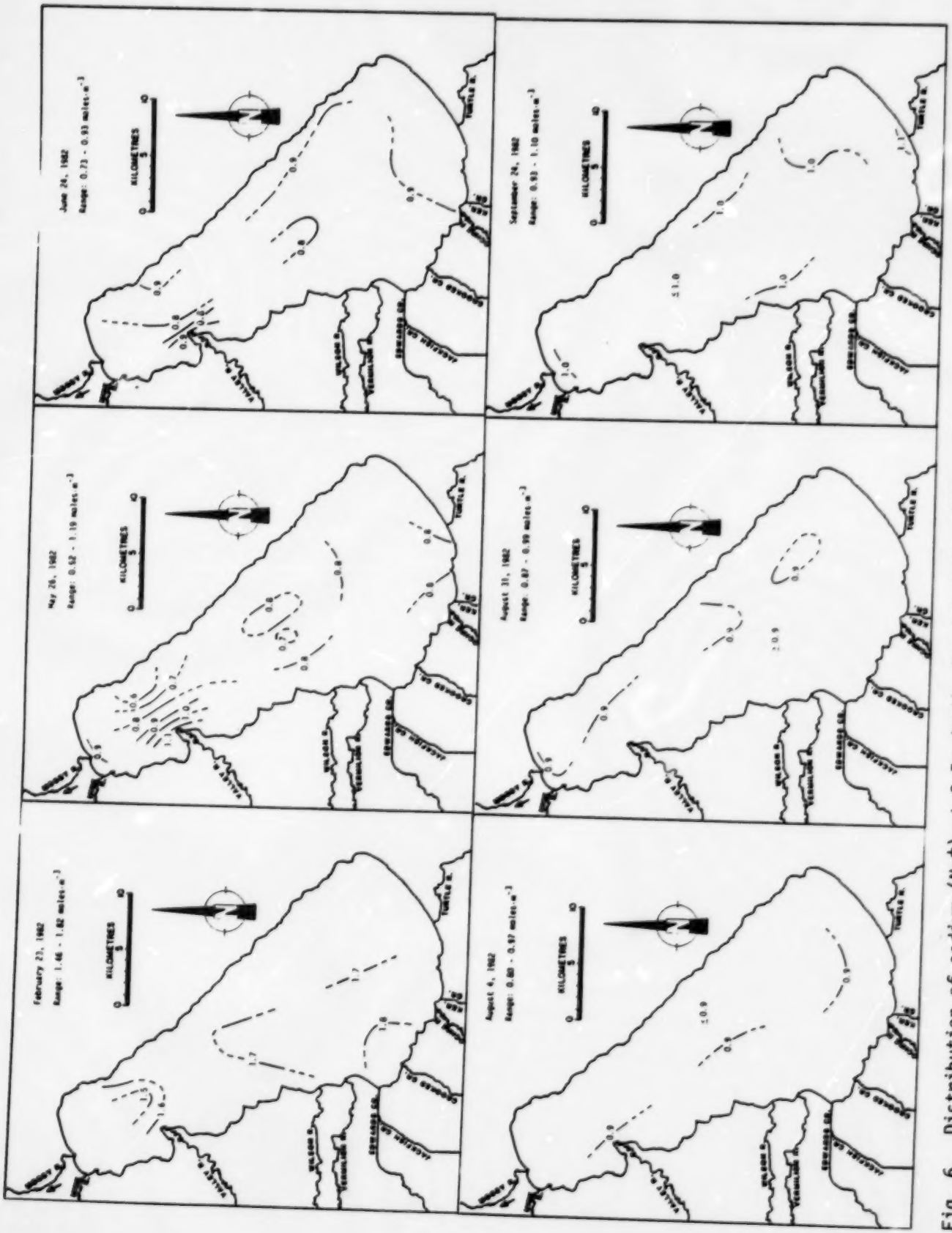

Fig. 6. Distribution of sodium (Na^+) at 0.5m depth, Dauphin Lake, 1982. Values from Table 10 converted to moles·m^{-3}. Isopleths are in 0.1 moles·m^{-3} intervals.

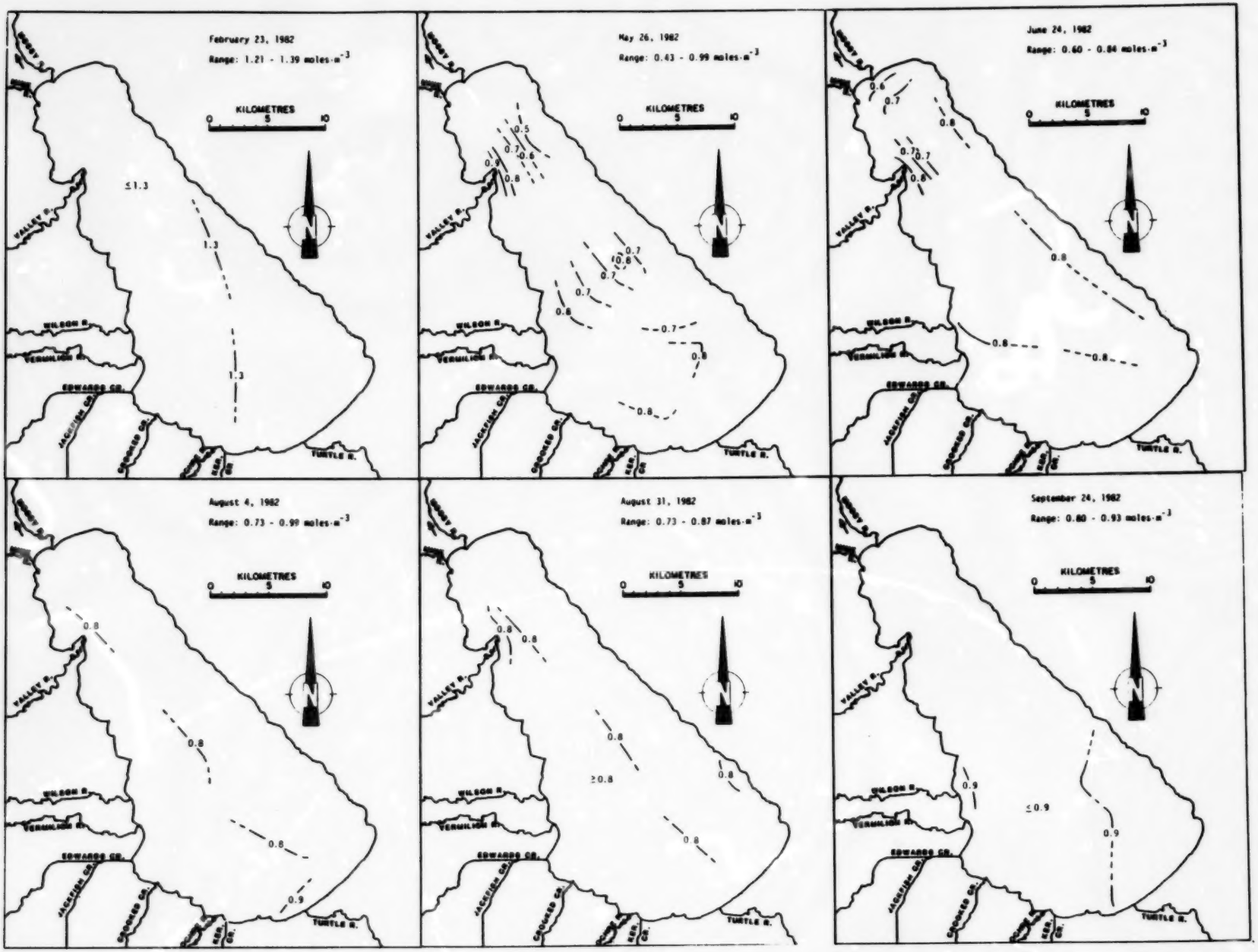

Fig. 7. Distribution of sulphate ($SO_4^=$) at 0.5m depth, Dauphin Lake, 1982. Values from Table 10 converted to moles·m^{-3}. Isopleths are in 0.1 moles·m^{-3} intervals.

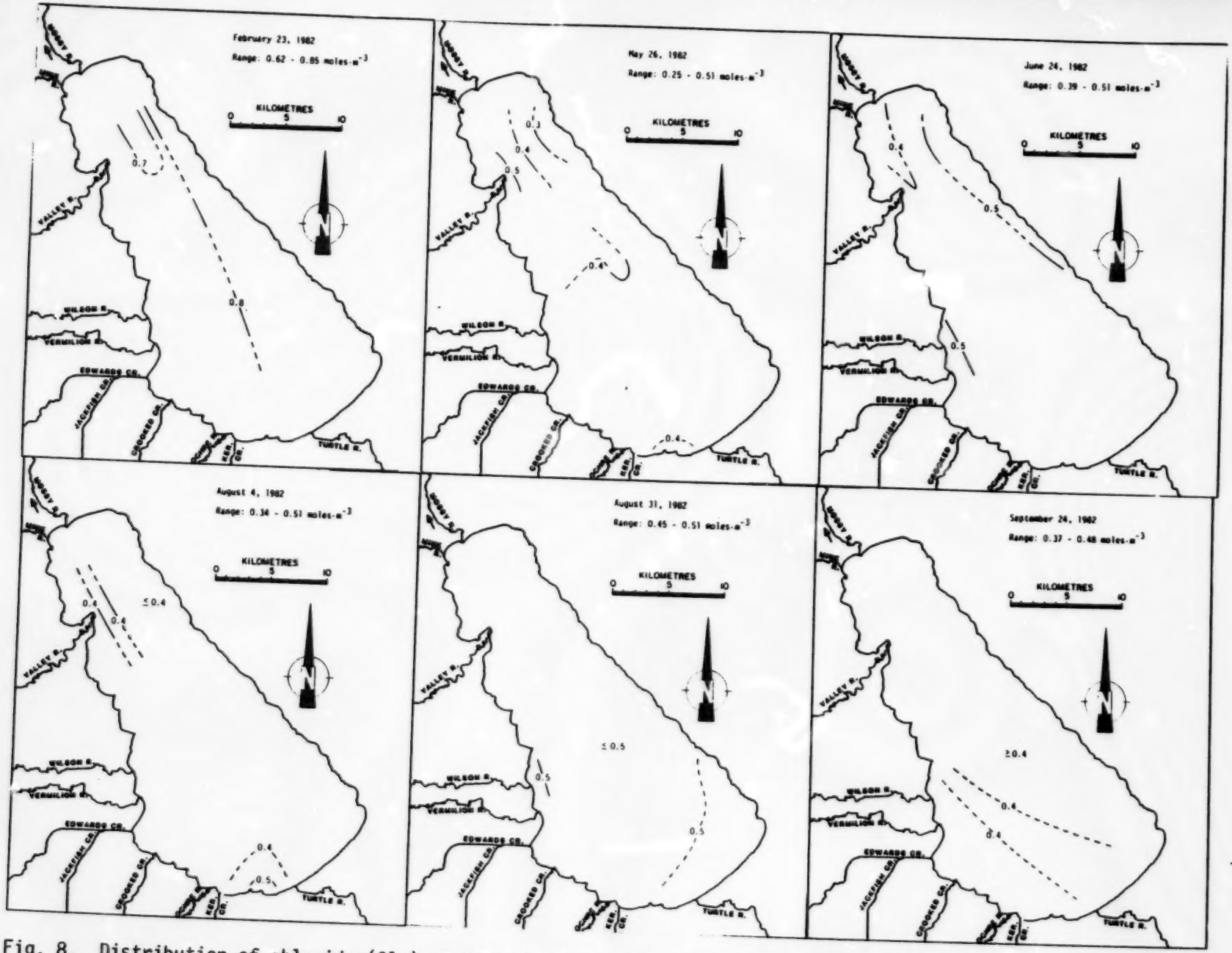

Fig. 8. Distribution of chloride (Cl^-) at 0.5m depth, Dauphin Lake, 1982. Values from Table 10 converted to moles·m^{-3}. Isopleths are in 0.1 moles·m^{-3} intervals.

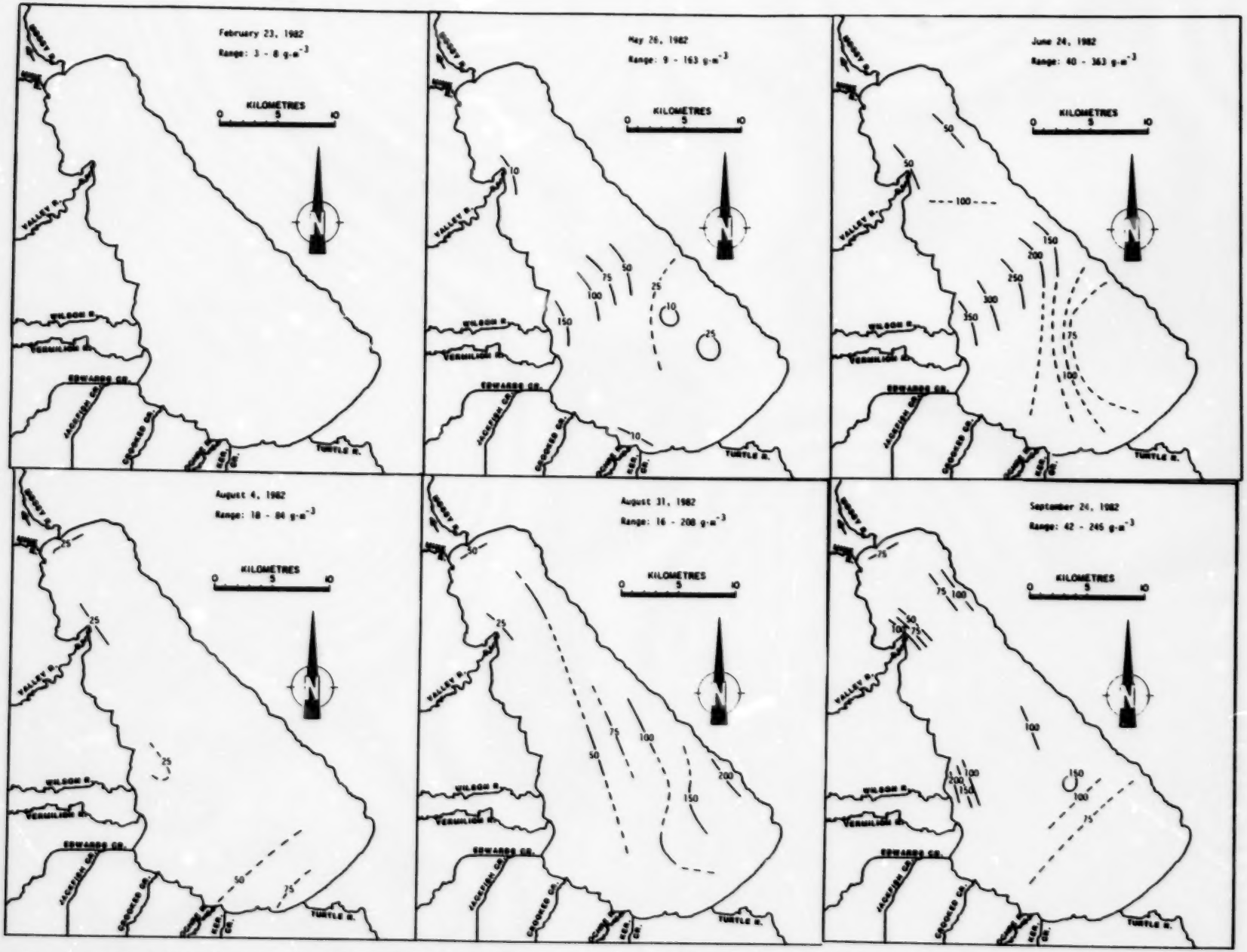

Fig. 9. Distribution of total suspended solids (T.S.S.) at 0.5m depth, Dauphin Lake, 1982. Isopleths are in 10,25,50,75,100,150,200,250,300 and 350 $g \cdot m^{-3}$ intervals.

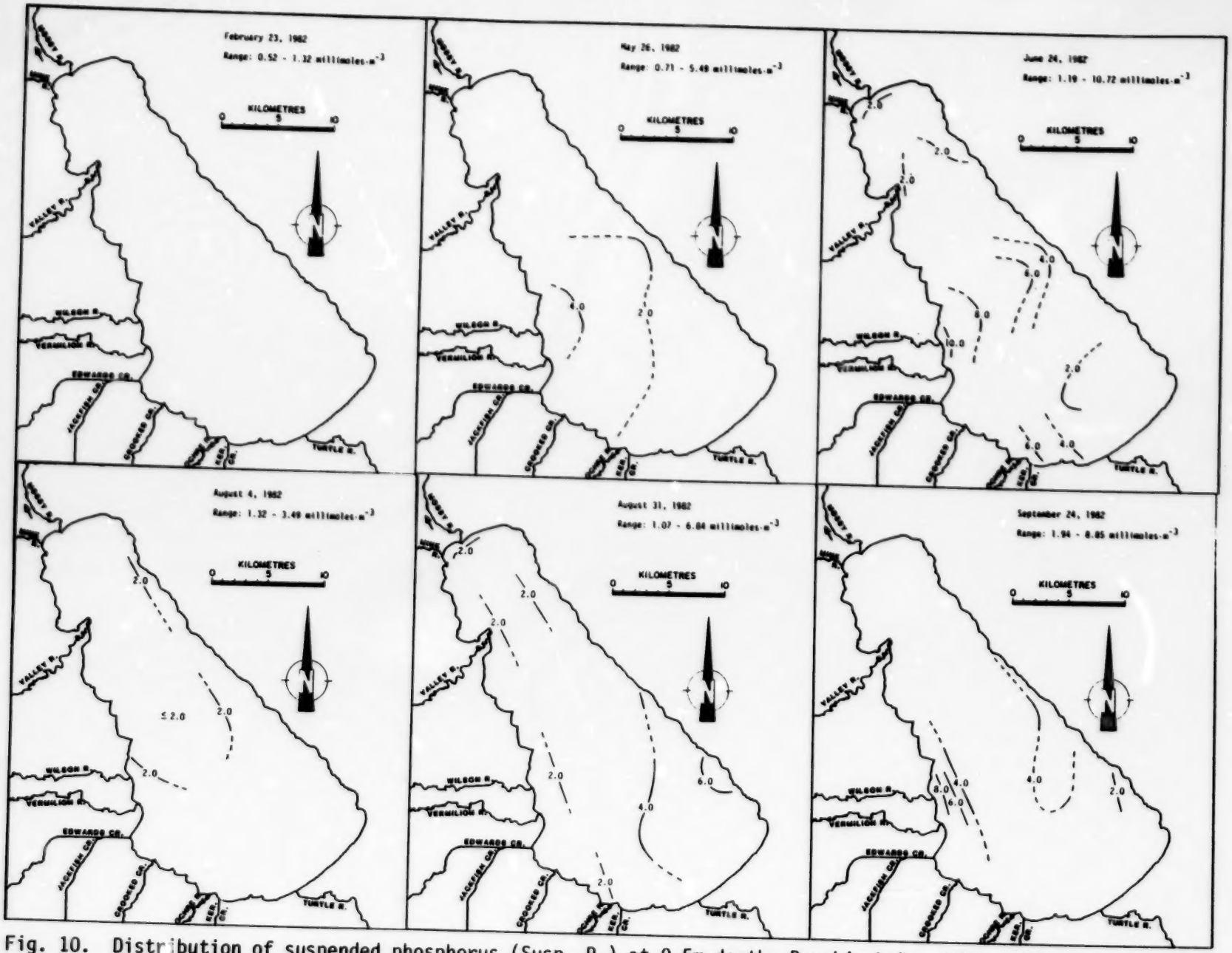

Fig. 10. Distribution of suspended phosphorus (Susp. P.) at 0.5m depth, Dauphin Lake, 1982. Values from Table 10 converted to millimoles·m^{-3}. Isopleths are in 2.0 millimoles·m^{-3} intervals.

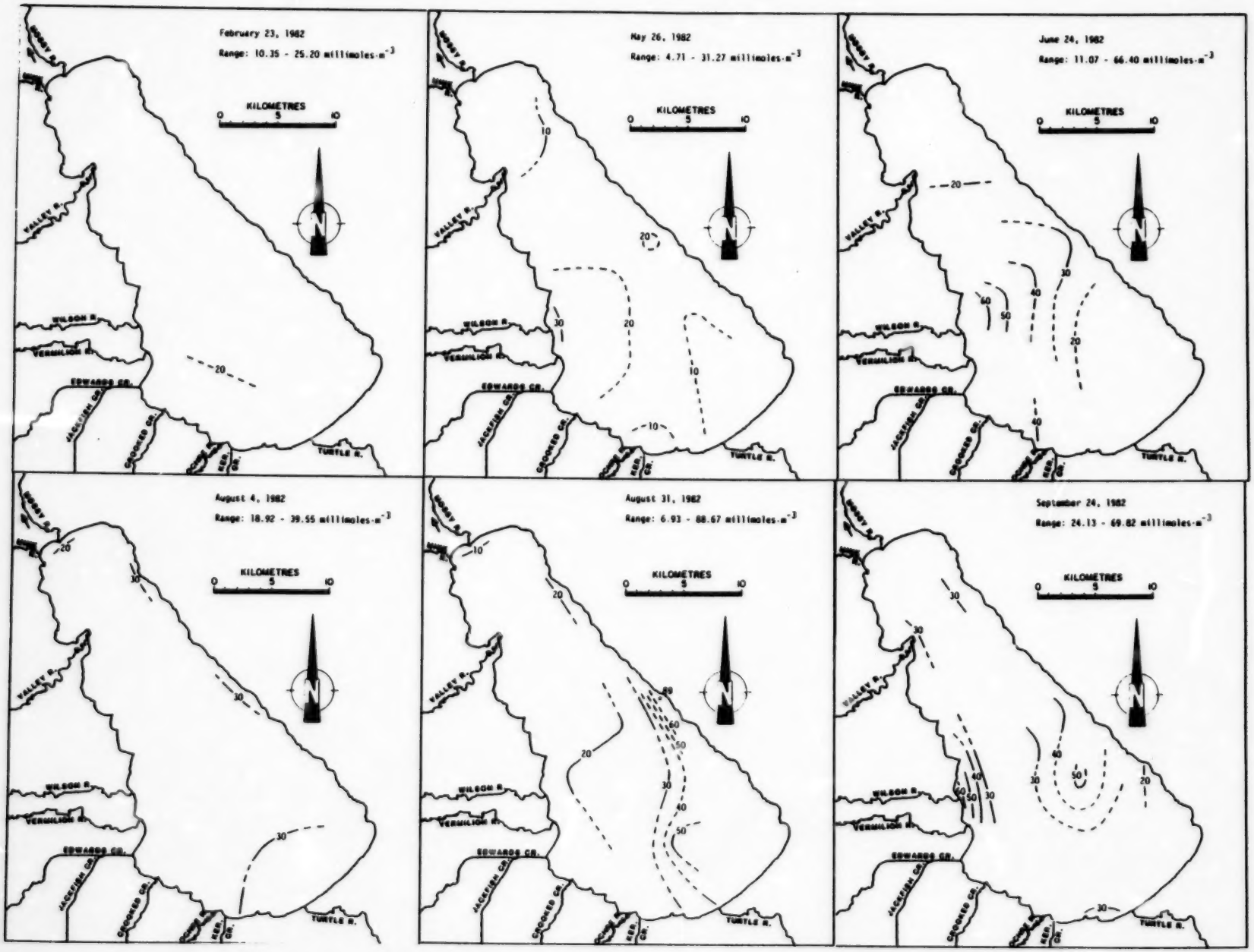

Fig. 11. Distribution of suspended nitrogen (Susp. N.) at 0.5m depth, Dauphin Lake, 1982. Values from Table 10 converted to millimoles·m^{-3}. Isopleths are in 10,20,30,40,50 and 100 millimoles·m^{-3} intervals.

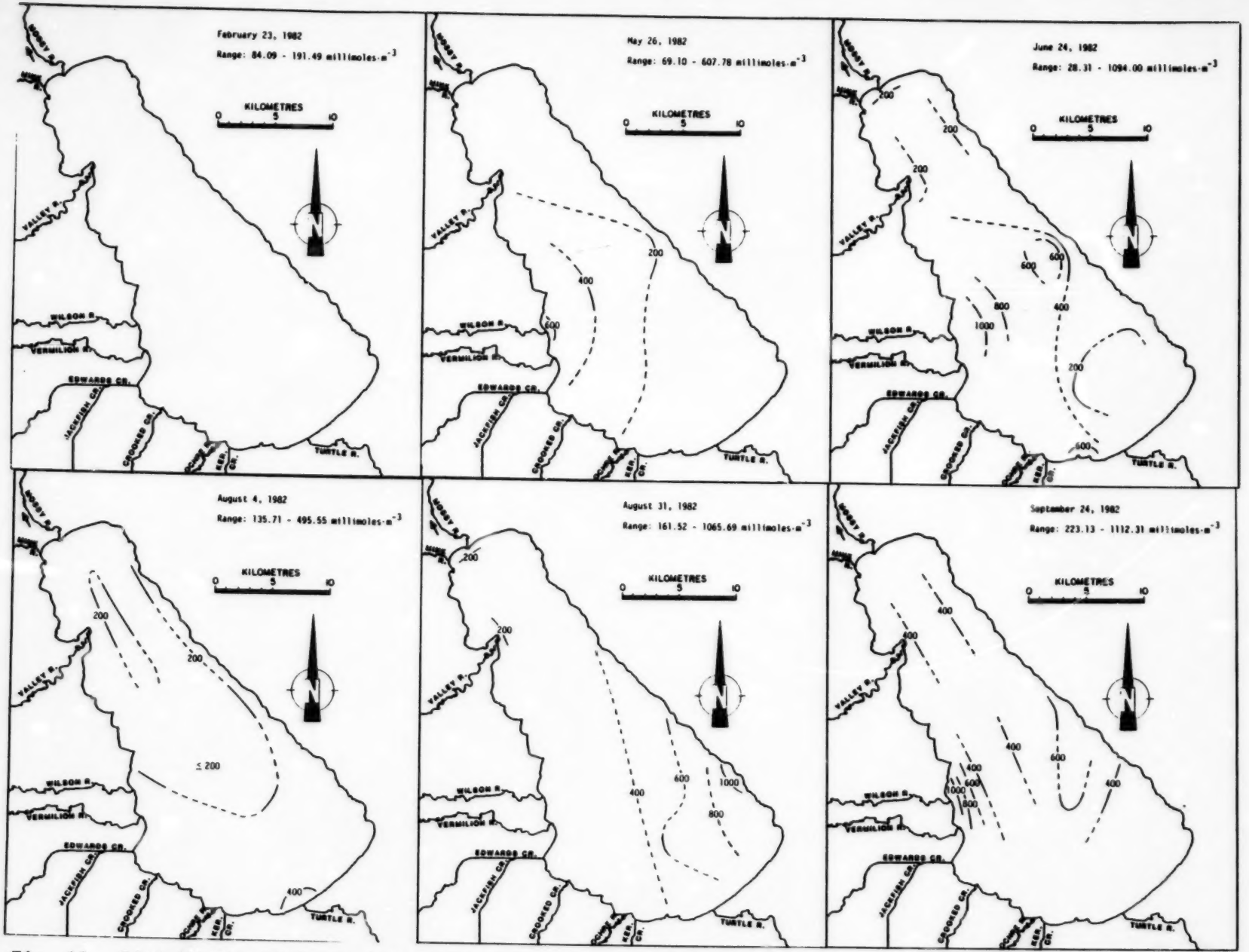

Fig. 12. Distribution of suspended carbon (Susp. C.) at 0.5m depth, Dauphin Lake, 1982. Values from Table 10 converted to millimoles·m^{-3}. Isopleths are in 200 millimoles·m^{-3} intervals.

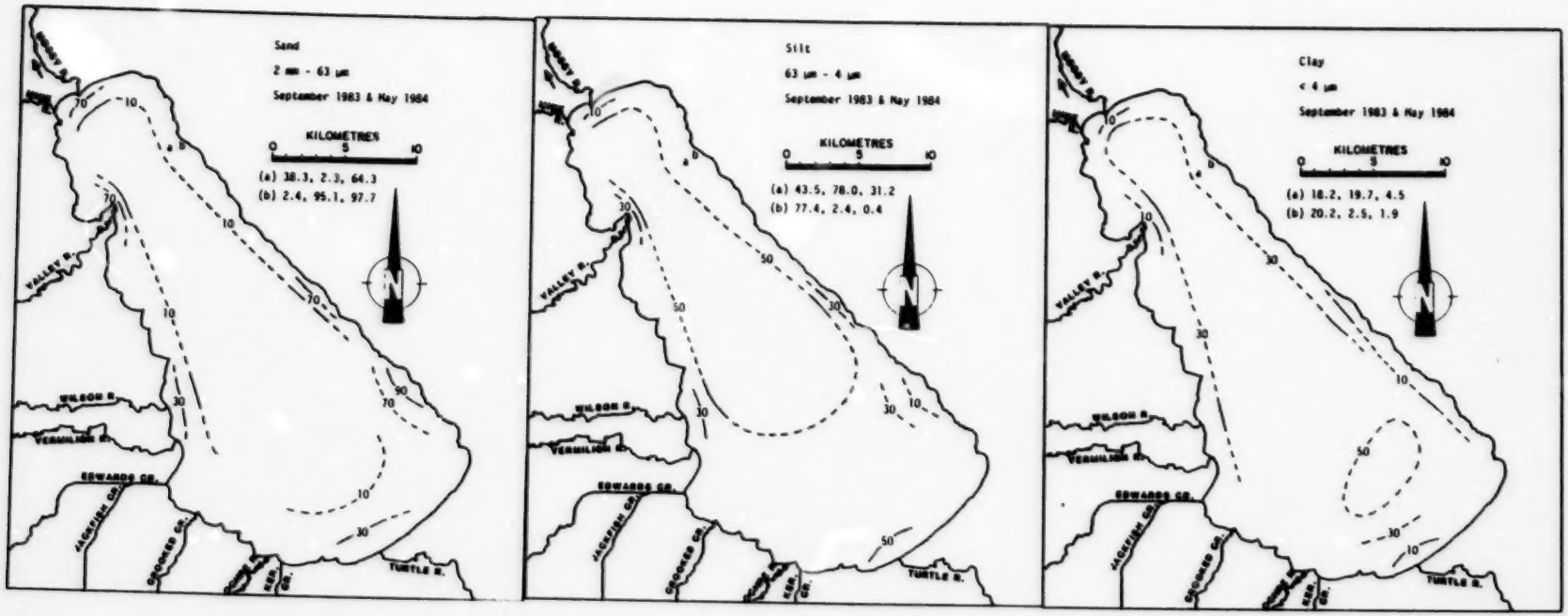

Fig. 13. Distribution of sand, silt and clay sediments, Dauphin Lake, 1983 and 1984. Percent sand, silt and clay from 3 different samples from station 17(a) and station 18(b) are given.

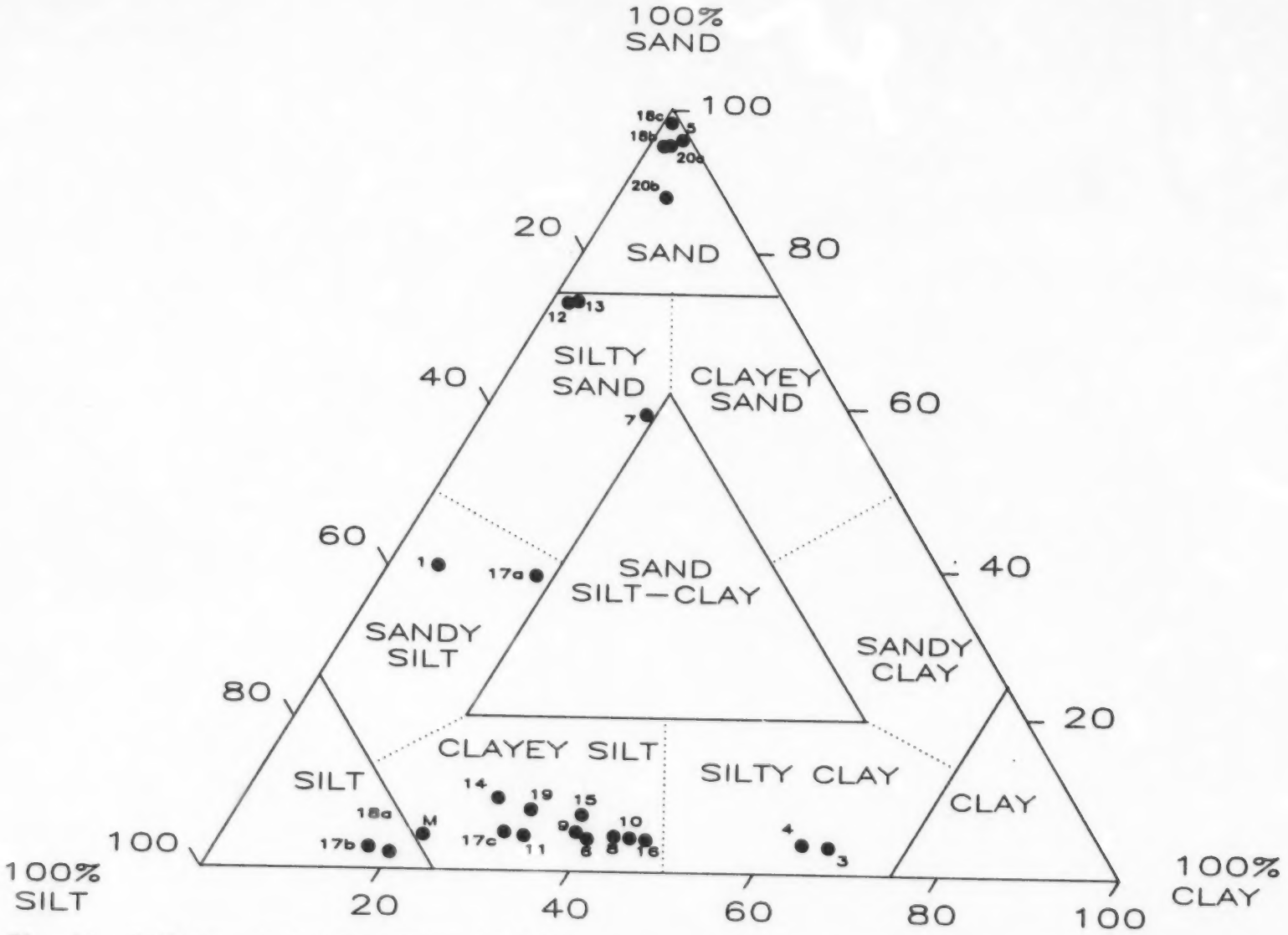

Fig. 14. Trilinear plot (after Shepard 1954) of surface sediments, Dauphin Lake, 1983 and 1984.